ILLINOIS LOESS

Variations in Its Properties and Distribution

A Pedologic Interpretation

By Guy D. Smith

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Illinois Loess—Variations in Its Properties and Distribution: a Pedologic Interpretation

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IN ILLINOIS approximately 70 percent of the upland soils have been formed primarily from loess, with little or no admixture of other parent materials. There is reason to believe that many other upland soils which occur in regions where loess cannot be identified with certainty have been influenced to varying degrees by this material.

The presence of extensive areas of loess in Illinois and other parts of the Mississippi Valley has been recognized for many years. The earliest students of this loess noted that its occurrence was related to the flood plains of the major streams and to the Iowan drift sheet. While there has been prolonged discussion of the agent by which the loess was transported and deposited; there was general early agreement concerning the character of the deposits. It was apparent to early workers that the loess blanket is thickest immediately next to the flood plains of the major streams; that the deposits along the east sides of the valleys are thicker than those along the west sides; and that the texture of the loess is coarsest close to the valleys.

As detailed soil surveys were made over the loess-covered portions of the Mississippi Valley, it was repeatedly observed that the character of the soils developed in the thick loess close to the rivers differs from that of the soils developed in the thinner loess deposits occurring at some distance from the rivers. But no theory was developed which adequately explained why soils of different character should be associated with loess deposits of different thicknesses or with differences in the distance from the loess source.

The purpose of this investigation was to determine the character of the loess deposits as related to distance from their source. Such knowledge may aid in understanding the association of soil character with loess depth and with distance from the loess source and therefore be of immediate value in mapping soils.

All data for this study, with the exception of that for Fig. 3, showing loess depths in Illinois, were collected by the author during 1936-1940, mainly in nine counties of south-central Illinois: Menard,

Sangamon, Christian, Shelby, Effingham, St. Clair, Clinton, Jefferson, and Cass. Fig. 3 is based on data compiled during 1930-1940 chiefly by R. S. Smith and E. A. Norton in their work of surveying Illinois soils, but also by others working with them.

The Illinois soil maps show belts of soils running more or less parallel with Mississippi, Illinois, and Wabash rivers, all important sources of loess. There is a pronounced tendency for the Prairie,[a] Wiesenboden, and Gray Brown podsolic soils, which are found in the deeper loess deposits, to be replaced by Planosols in areas where the loess deposit is thin and overlies weathered materials. The productivity of the Planosols, even when given complete treatment, is much lower than that of the Wiesenboden and Prairie soils occurring in the deep loess regions of the state.

Soil maps of surrounding states show that these conditions are not confined to Illinois. Indiana soil maps reveal a belt of soils belonging to the Princeton catena[b] lying immediately next to the Wabash river valley, a major source of loess. Farther back from the river, where the loess blanket is thinner, the maps reveal a belt of soils belonging to the Alford catena.

Missouri soil maps commonly show a belt of Knox soils immediately adjacent to Missouri river, another source of loess. Farther back from the Missouri river bluffs a belt of Union soils has been mapped. Similar changes are shown in the soils which were developed under a prairie vegetation. The Marshall series, which are Prairie soils, are mapped closest to Missouri river, where the loess is thickest, and the Putnam silt loam, which is a Planosol, is mapped farther to the east, where the loess is thinner.

In Iowa the soils derived from loess seem to occur in somewhat similar belts. Brown[8*] recognized that the character of the soils varied with the character of the loess, and divided the loess into three groups, partly on the basis of origin and partly on the thickness of the loess deposit. He described the Marshall series as occurring along Missouri river, where the loess is thickest, and the Edina, a Planosol, as occurring farther back from the river, where the loess is thinner.

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[a]The term "Prairie soil" as used in this bulletin has a restricted meaning and is used in accordance with the definition given in the 1938 Yearbook of the U. S. Department of Agriculture, "Soils and Men." The term refers only to soils having a brown to very dark brown surface, with good internal drainage.

[b]The term "catena" refers to a group of soils which have developed from similar parent material of the same age and under similar vegetation but which differ in profile characteristics because of the varying drainage conditions under which they have developed.

*Figures starred refer to the literature citations on pages 183 and 184.

REVIEW OF LITERATURE

Origin and deposition of Mississippi Valley loess. Altho many loess sheets have been identified in various sections of the Mississippi Valley, only two are known to occupy significant areas in Illinois. Leighton and MacClintock[19*] have recognized the Late Sangamon and Peorian loess sheets and described them as differing in color, the Peorian weathering to a buff or brown and the Late Sangamon to a pinkish or grayish brown.[a]

In his review of literature concerning the origin of loess, published in 1934, Scheidig[25*] lists some twenty hypotheses advanced at one time or another to explain the presence and distribution of the loess. While loess may vary from one area to another with respect to source and method of deposition, there seems now to be fairly general agreement that the Mississippi Valley loess is a wind deposit and that its source was the flood plains of the Pleistocene rivers.

Chamberlain[10*] presented this hypothesis, assuming among other things, the development of extensive flats over which glacial silts were spread during great periodic extensions of glacial waters caused by periods of warm weather in the melting season or by warm rains or both. Chamberlain reasoned that after the waters had retreated the extensive silt-covered flats would become exposed to the sweeping influence of the wind, and when they had dried the silt would be borne in great quantities over the adjoining uplands. His hypothesis appears to be borne out by the presence of the major loess deposits adjacent to the courses of the major streams which carried the glacial waters. Chamberlain further pointed out that, according to this hypothesis, there must be a relationship between the breadth of the fluvial deposits and the extent and massiveness of the aeolian deposits on the adjacent uplands. That the breadth of the river bottoms is related to the extent and massiveness of the loess deposits is shown on page 152.

Keyes,[14*] arguing that the wind was the agent of loess deposition, pointed out that mud flats along rivers furnish a source of loess and presented evidence of current deposition of loess along Missouri river. He further reasoned that the loess deposit should be thicker on the leeward side of the mud flats than on the windward.

A modern example of the deposition of loess in the manner suggested by Chamberlain and Keyes has been described by Tuck[34*] in

[a]The term "Peorian loess" as used in this bulletin refers to all the post Sangamon loess, since the separation of deposits of Iowan, Tazewell, Cary, and Mankato ages, as defined by Leighton,[18*] cannot be made consistently outside the regions covered by Wisconsin till or outwash.

Matanuska Valley, Alaska. With the glaciers standing 20 to 45 miles up the valleys, the glacial rock flour is deposited down the valley in the many and constantly changing channels or on the broad flood plains. Tuck describes a pall of dust as being visible over Palmer and the surrounding country in dry weather and even in winter. Section corners staked in 1913 were found to be covered to a depth of several inches in 1935.

Sources of loess other than the river flood plains were undoubtedly present. Hobbs[13*] has described current deposition of loess from glacial outwash plains in Greenland. The outwash plains dry up in the fall of the year when the storms off the ice have greater frequency and increased violence. The visibility at Mt. Evans Observatory, 25 miles from the ice front, is greatly reduced by the dust, and caribou antlers in the tundra areas are buried by the dust to as much as one-third of their height. Hobbs suggests that the Iowan border loess was deposited under conditions similar to those he describes in Greenland.

Since conditions during the deposition of the loess along the river flood plains were not necessarily the same as those during the deposition of the Iowan border loess, and since many of the variations in soil character are found in the loess originating in the river flood plains, the balance of this discussion will be concerned with the loess which borders Mississippi and Illinois rivers.

Time of deposition. Loess deposition along the river flood plains could conceivably have taken place during the advance, the climax, or the retreat of the ice. Very little accumulation would be expected during interglacial periods unless during such periods extensive erosion of the till deposits took place. Visher,[37*] citing the fossils of the loess and the pebble bands of the till, concluded that the loess was deposited principally during the retreat of the ice rather than at the climax or during the interglacial periods. Leighton[17*] observed that the calcareous Peorian loess rests on calcareous Iowan till and both above and below calcareous Wisconsin till. In each case where the loess is thick enough to be calcareous, he found that the underlying till is also calcareous and shows no profile of weathering or soil development, and he concluded that the Peorian loess deposition was continuous from the retreat of the Iowan ice thru the Wisconsin glaciation.

Antevs[1*] has studied the length of time required for the retreat of the Wisconsin ice, a period during a great part of which conditions should have been favorable for loess deposition. He concluded from his studies of the varved clays that, "The last ice sheets had their greatest extent and began to wane about 40,000 years ago. This figure

may be less than 10,000 years too large or too small." The retreat of the ice, starting about 40,000 years ago, may have lasted for 29,000 years, according to his counts of the varved clays.

In a later paper Antevs[2*] reviews the probable durations of the various stages of the Pleistocene and concludes that the late Mankato ice began to retreat from Iowa about 22,000 to 25,000 years ago. He placed the earliest advance of the Wisconsin ice (Iowan) at between 65,000 and 70,000 years ago. Thus conditions favorable for loess accumulation in Illinois may have persisted from about 70,000 years ago to about 22,000 years ago.

Shimek,[27*] on the basis of his studies of the loess fossils, concluded that the deposition of the loess was slow and continued thru a period of considerable duration.

Climatic conditions during loess accumulation. Shimek[28, 29, 30*] concluded from his studies of the loess fossils that "the conditions under which the loess was deposited were not essentially different from those which prevail in the Mississippi Valley today." His conclusions were based on the observation that the loess fossil fauna of a certain area, composed largely of terrestrial, herbivorous air-breathing mollusks, does not differ materially from the fauna of the same area today. He says, "Such differences as do exist [between the modern and fossil faunas] point to a drier climate in the northern part of the loess-covered area than that of today."

Baker,[3*] in reconstructing conditions during the period of loess deposition, says, "The fauna of the loess probably lived under conditions practically the same as those obtaining today. The river bluffs were forested much as at present . . . . and here the larger species lived. Many of the smaller species probably inhabited open woods or thickets, or even the open prairies, as they do today." Baker concluded that differences in the fossil fauna of the loess and the modern fauna are best explained by the assumption that the isotherms were displaced southward during at least part of the periods of loess deposition. He says, "This does not necessitate the assumption that the climate was arctic but simply that an isotherm that now occurs in southern Michigan and Wisconsin moved southward temporarily to central or southern Illinois."

It would seem that Baker and Shimek are in essential agreement that the climate in certain regions during the period of loess deposition was very similar to that in the same regions today. Neither has found evidence of great drouth or extreme cold. Nor would there seem to be serious conflict between the concept of a mild climate during the

period of loess deposition and the concept of deposition during the retreat of the ice, for it has always been assumed that the glaciers retreated as a result of an increase in temperature.

Character of loess deposits as related to distance from river flood plains. Altho students of the loess have unanimously agreed that the loess blankets of the Mississippi Valley become thinner with distance from the bluffs along the river flood plains, search of the literature reveals only one instance where quantitative measurements of the rate of thinning were made. Krumbein[15*] reports a study of the depths of loess along Mississippi river near Lomax and Dallas City, Illinois. Within the limits of 2 to 9 miles from the bluff he found the loess thinning according to the equation $Y = e^{-.17\,X}$, where Y is the depth of loess, and X the distance from the bluffs. Between limits of 9 and 13 miles from the bluffs Krumbein was unable to detect any thinning in the loess. Measurements of the thickness were not made at distances greater than 13 miles. He recognized that an extrapolation of the above equation to the bluff would result in an underestimation of the loess thickness at the bluff, but he explained that the greater thickness at the bluff might be due to the piling up of sand.

Leverett [20*] and others have reported that the loess at the bluff is coarser in texture than the loess several miles removed. While many mechanical analyses of the loess have been reported, no instances were found where the changes in texture with distance from the bluffs were measured quantitatively. Krumbein[15*] states that on theoretical grounds the size changes would be expected to be exponential.

No quantitative studies of the composition of the loess at varying distances from the bluffs were found in the literature. However, Fuller and Clapp[11*] have pointed out that along Wabash river in Indiana the loess close to the bluffs is high in carbonates, while the loess found in the thinner deposits several miles from the bluffs is very low in carbonates. They designated the bluff deposits as marl loess and the other deposits as common loess, attributing the differences in composition to differences in origin.

Soil character as related to loess depth and distance from river bluffs. From deposits of Peorian loess of decreasing thickness at increasing distances from the river bluffs, samples of Gray Brown Podsolic soils were collected and studied by Bray and DeTurk.[7*] They have pointed out that the base-exchange capacity of the B horizon increases and the degree of base saturation decreases as the loess thins.

Norton[22*] studied the morphologic changes in grassland soils de-

Hartsburg 1 | Muscatine 2 | Herrick 3 | Cowden 4 | Cisne 5

FIG. 1.—MONOLITHS OF GRASSLAND SOILS (SILT LOAMS) DEVELOPED IN PEORIAN LOESS DEPOSITS OF VARYING THICKNESSES

veloped from loess deposits of varying thicknesses and described five groups or stages of development in soils:

1. The first group, found nearest the bluffs, has a dark-colored granular surface, shows little definite zone of clay accumulation, and is highly saturated with bases.
2. The second group has a dark-colored granular surface with dark coatings on the particle faces in the subsoil, a perceptible zone of clay accumulation altho horizon separations are indefinite, and is moderately saturated with bases.
3. In the third group the dark-colored surface has a distinct grayish cast, there is a definite zone of clay accumulation with sharp horizon separations, and base saturation is moderately low.
4. The fourth group has a nongranular brownish gray surface, a gray ashy subsurface, a heavy plastic zone of clay accumulation with well-developed structural particles, sharply separated horizons, and the soils are relatively unsaturated.
5. In the fifth group there is a friable gray surface, an ashy gray subsurface, a heavy and plastic zone of clay accumulation, sharply defined horizons, and a high degree of unsaturation.

The difference in appearance between these five groups of soils is shown in Fig. 1, a photograph of the upper 40 inches of five soil monoliths. The first group, as defined by Norton, is represented by a monolith of Hartsburg silt loam, the second by Muscatine silt loam, the third by Herrick silt loam, the fourth by Cowden silt loam, the fifth by Cisne silt loam. Hartsburg and Muscatine are Prairie soils, Cowden and Cisne are Planosols, and Herrick is transitional in character between the Prairie soils and the Planosols. This plate illustrates the gradation in color of the surface from a very dark grayish brown, or almost black, to gray and the development of the ashy-gray subsurface in Groups 4 and 5, represented by the Cowden and Cisne silt loams.

Norton further points out that altho the outstanding characteristics of the later stages of development—the gray ashy subsurface and the heavy plastic claypan—have been frequently attributed to formation under slow drainage, soils formed on the smooth, gently rolling slopes in the absence of a high-water table also have these characteristics.

Bray[4, 5, 6*] has reported studies on the chemical and mineralogical composition of grassland soils in the various groups or stages of development as defined by Norton. These studies, while showing small differences in the character of the primary and secondary minerals, reveal a very great difference in the distribution of the secondary minerals. In the Hartsburg soil, developed in the thickest loess, there is evidence of very little movement of the clay minerals. In the Cisne, developed from the thinnest loess, the secondary minerals produced in the A horizon by weathering have become concentrated in the claypan, or B horizon.

Bray[6*] has also published detailed analytical data covering the soils illustrated in Fig. 1. These profiles were collected in a straight line along Traverse 1 (Fig. 2). He shows that the organic-carbon content of the A_1 horizon decreases from 2.53 percent in the Hartsburg profile developed near the bluff to 1.51 percent in the Cisne silt loam. In the same soils the colloid content of the A_1 horizon decreases from 22.3

Fig. 2.—Location of Traverses Along Which Studies of Loess Were Made for This Report

percent in the Hartsburg to 12.0 percent in the Cisne, while the colloid content of the B_1 horizon increases from 31.6 percent in the Hartsburg to 42.0 percent in the Cisne. Bray's unpublished data from these profiles show that the saturation of the A horizon with bases decreases from about 90 to about 17 percent, while the saturation of the B horizon decreases from about 96 to about 48 percent. Intermediate soils show intermediate profile characteristics.

While the differences in the soils developed from Peorian loess blankets of varying thickness have received some attention, search of the literature reveals little work on the problems relating to the causes of the differences. Bushnell[9*] has noted differences in the lime

content of the thick and thin loess blankets. Norton and Winters[23*] suggest that ". . . . the character of underlying weathered zones influences both the direction and rate of surface horizon development. . . . . Thick, and thoroly weathered subjacent material increases the rate of soil development." No mechanism for the influence of the underlying weathered zones was postulated.

Bray and DeTurk[7*] suggest other possible causes for the changes in soils with distance from the river bluffs. They say, "Either within the same loess region a larger proportion of the finer material was blown inland from the Mississippi river, while a greater proportion of the coarse material was dropped nearer the river, or the entire Peorian deposition covered a long period of time, and the distance to which it (the loess) was carried gradually receded so that the age of the material gradually decreases as the river is approached. Of course, there is the further possibility that the profiles nearest the river are influenced by Post-Wisconsin loess deposition to a greater extent than is at present believed as a result of observations in the field."

METHODS OF INVESTIGATION

Field Methods

Measurement of loess depths. Measurements of the loess at varying distances from the river bluffs were greatly facilitated by the unpublished records upon which Fig. 3 is based. With these records as a guide, measurements of depth were made in as nearly a straight line as possible in the direction of the winds prevailing during the period of loess deposition.

Two traverses were made in order to study the rate of change in loess depth with distance from the bluffs. Traverse 1 started in the northwestern part of Menard county, Illinois, and extended in a southeasterly direction thru Menard, Sangamon, Christian, Shelby, and Effingham counties. Traverse 2 started in St. Clair county near Collinsville, and ran in an east-south-east direction thru St. Clair, Clinton, and Jefferson counties. The locations of these two traverses are shown in Fig. 2. Traverse 1 takes a more southerly direction than Traverse 2 because it was necessary in making it to avoid the Wisconsin drift boundary, where the discontinuity in the age of the till affects the loess depth.

West of Traverse 1 investigations were also made in Cass county (*see page 158*).

The measurements of thickness along the traverses were made in

road cuts and by deep borings where topographic situations seemed to preclude any possibility of significant changes in thickness thru erosion or deposition of wash from adjacent higher land. The topography was restricted to nearly level or very gently sloping ridge tops where the slope seldom exceeded 1½ percent. If any doubt existed as to the possibility of erosion, several measurements were made in the same vicinity on different ridges, and measurements which deviated widely from the modal measurement were rejected. In two cases (*page 158*) the depth of loess was too great to be measured. In these cases the depth of Peorian loess was estimated from the difference between the elevation of broad level tablelands and outcrops of the contact between the Peorian and Late Sangamon loess in narrow, deeply incised valleys.

The Late Sangamon and Peorian loess sheets were separated on the basis of color and of effervescence with acid. Except for exposures directly on the bluffs, the Sangamon loess was leached free of carbonates before the Peorian deposition began. When the basal part of the Peorian loess was calcareous, the line of separation was fairly sharp; the transitional zone between the two loess sheets was usually less than 18 inches and frequently less than 12 inches thick.

Where the Peorian loess had lost its free carbonates, the separation from the Late Sangamon loess could sometimes be made on the basis of the color differences pointed out by Leighton and MacClintock.[19*] As a rule, however, the separation between the Late Sangamon and the Peorian loess sheets was not possible in the field unless there were carbonates remaining in the Peorian loess or unless the Peorian loess sheet was at least 75 inches thick.

The separation between the Late Sangamon loess and the Illinoian till was based on texture, the Illinoian till containing pebbles and large quartz sand grains. This separation was difficult to make because the soils developed from the Illinoian till prior to the deposition of the Sangamon loess frequently had a silt loam surface, and the change in texture between the silty Sangamon loess and the silty A horizon of the buried till soil was not great.

Another difficulty in this separation was that sometimes there appeared to have been a mixing of the loess and the till. Where the Late Sangamon loess was thin, less than 3 feet thick, the annual increment was small, and mixing with the Illinoian till soil could have been produced either by frost or by animal action. In poorly drained areas crayfish (Astacidae) appear to have been particularly abundant. These crustaceans burrow into the soil in wet places to a depth of several

feet, piling excavated material at the surface in the form of chimneys. Small rocks, up to 2 centimeters in diameter, are frequently found in these chimneys. As a result of these activities, areas are commonly found where the mixing has been so great that no reasonable estimate of the loess thickness can be made. Mixing by animals of thin loess with underlying materials has been described by Savage.[24*] In well-drained areas the mixing of the loess and till seems to have been much less. In such areas, however, depth measurements are unreliable because of the possibility of removal of a portion of the loess by erosion.

To obtain the data used for the construction of Fig. 3, the map of the loess depths (*opposite page 152*), observations of the depth of the loess blanket were made by deep borings and by examination of road cuts in areas with gently undulating or level topography. While some errors were undoubtedly made owing to erosion of a portion of the loess or possibly to deposition of wash of local origin, the large number of observations, in excess of 1,300, tends to average out such errors.

Collection of samples. Changes in the loess brought about by weathering processes following the period of loess deposition might easily obscure any differences in the loess deposited at different distances from its source. To hold the effects of weathering to a minimum, all samples were collected from deeply buried horizons containing primary carbonates.

An attempt was also made by careful selection of samples to eliminate differences in time of deposition and, in so far as possible, variations in underdrainage during the period of deposition. The time of deposition was controlled by sampling in each case from the same portion of the Peorian loess. It was found along Traverse 1, thru Menard and Sangamon counties, that primary carbonates could be consistently found only thruout the lower quarter of the Peorian loess. In two samples taken close to the bluffs for mechanical analysis, the lower quarter of the Peorian loess was too deeply buried to be accessible, and the samples were collected from the upper portion of the calcareous loess section. Along Traverse 2 samples were taken from the lower one-sixth of the Peorian loess.

Preliminary studies showed that differences in the carbonate content of the loess were associated with differences in drainage as well as with distance from the loess source. It seemed necessary, therefore, to take samples in so far as possible, where the drainage of the loess was neither unusually poor nor unusually good. Since the drainage

could not be easily estimated, considerable variability probably occurred in the samples, but every effort was made to eliminate samples from locations where weathering had been influenced by conditions of poor drainage. Depressional areas were avoided, and attempts were always made to collect samples only where the surface of the Late Sangamon loess had sufficient slope to provide surface drainage. Samples for mechanical analysis were taken in two instances from poorly drained sites when well-drained samples could not be found.

Laboratory Methods

Sample preparation. The Peorian loess samples were first air-dried, gently crushed with a rolling pin, and then screened to eliminate hard lime concretions. One of the determinations desired was the content of primary carbonates, and the screening out of the concretions was designed to remove as much of the secondary carbonates as possible. Not all of the secondary carbonates could be removed in this way, for at times the calcium carbonate accumulates in a soft powdery form which is very difficult to identify or separate from the loess.

Mechanical analysis. The samples were subjected to mechanical analysis by the pipette method, following the procedure of Winters and Harland.[38*] One modification was the omission of the HCl pre-treatment of the samples. Total sands were determined by sieving, and pipette samples were withdrawn to give size fractions of 30, 20, 10 and 1 microns.

Determination of $CaCO_3$ equivalent. The calcium carbonate equivalent was estimated from the determination of total carbon in the samples. In such deeply buried calcareous samples as were collected, organic carbon has never been found to be present in more than traces, which can be safely neglected in the presence of large amounts of free carbonates. The determination of total carbon was made by the dry combustion method of Winters and Smith,[39*] omitting the use of MnO_2.

Fractionation into particle-size groups. Since the wind could deposit loess with different carbonate contents at different distances from the bluff if there were a concentration of the carbonates in certain size fractions, samples of the calcareous Peorian loess from near the bluffs were fractionated according to effective particle size. Dispersion procedure followed that of mechanical analysis, except that sodium oxalate was used in place of sodium carbonate. Separation according to effective particle size was effected by repeated suspension and decanta-

tion, with about ten suspensions and decantations for each size group. This method permitted some slight contamination of each size group with particles from other size groups. The size groups separated were the same as those determined by mechanical analysis.

DISTRIBUTION OF LOESS IN ILLINOIS

The thickness of the loess and its distribution over the state are shown in Fig. 3. Points where measurements were made are indicated by small dots. The study of loess thickness is not yet complete, and in many counties only fragmentary data are available. Boundaries between such areas are shown rather by dashes than by solid lines.

This map confirms the observations of Leverett[20*] and others that the belts of thick loess tend to follow closely the valleys of Illinois and Mississippi rivers, and that the loess deposits to the east of the valleys are thicker than the deposits to the west of the valleys. It also reveals that Chamberlain's[10*] requirement is met—that the broader the fluvial deposits the greater is the extent and massiveness of the aeolian deposits. This relationship was pointed out by Smith and Norton,[31*] altho Savage[24*] earlier had showed that the thickest loess deposits were to be found at points where the winds could sweep along the river flood plains for a considerable distance without obstruction by bends in the valley. It will be noted that the large alluvial plain in Mason and Cass counties is bordered on the east by broad belts of very thick loess. Similarly in St. Clair and Madison counties, where the Mississippi bottom widens and the northwest winds had a long sweep down the valley, there are broad belts of thick loess. Again in Jackson county the bottoms widen slightly, and the northwest winds had a long sweep down the valley, and once more the loess deposits become deeper and broader.

Conversely, in Adams and Hancock counties the Mississippi flood plain becomes very narrow, and to the east of this area the loess becomes very shallow.

In Carroll, Whiteside, and Henry counties broad belts of thick loess occur adjacent to alluvial deposits of Rock and Green rivers. Here the distribution of the loess might indicate that these alluvial plains were of less importance, and that the major part of the loess may be the border loess of the Iowan till. This area of deep loess is shown on Leverett's map[20*] of the Illinois Ice Lobe as Iowan border loess. Further study of the loess in this region is needed before conclusions can be safely drawn.

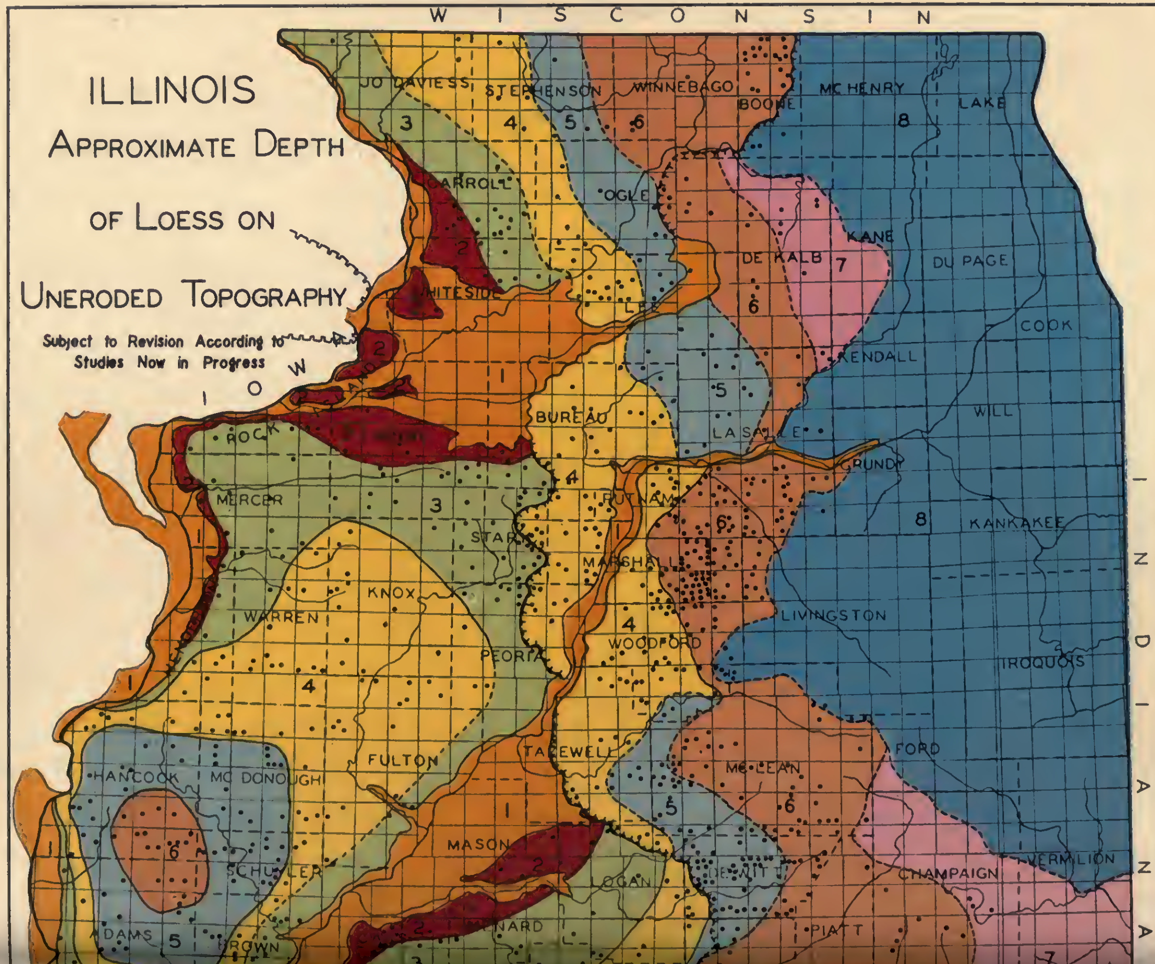
FIG. 3

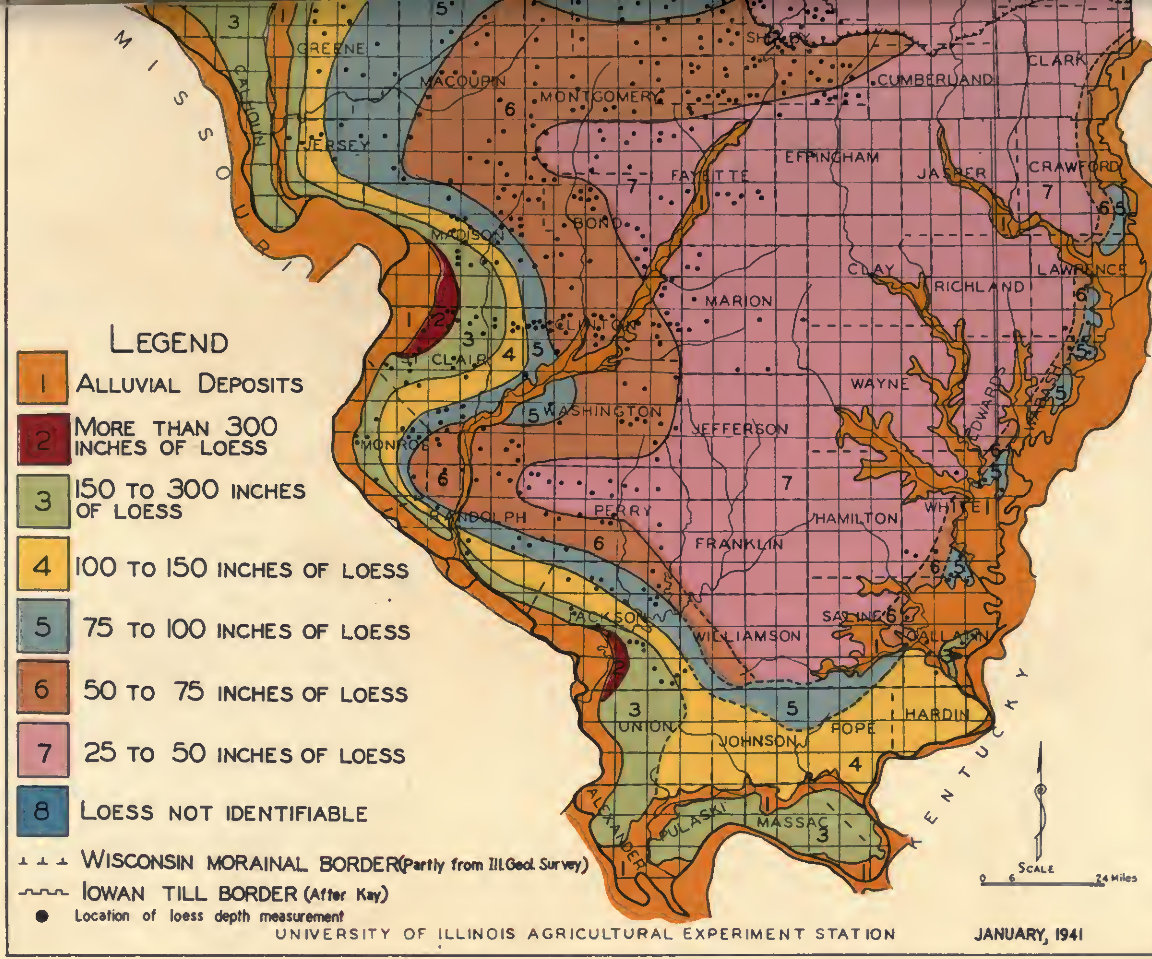
DEPTH OF LOESS IN ILLINOIS

(From data collected by members of University of Illinois Soil Survey, chiefly by R. S. Smith and E. A. Norton)

Correction

**Key 8 (the darker blue) should read—
Loess not identifiable or less than
25 inches thick**


ILLINOIS
APPROXIMATE DEPTH
OF LOESS ON
UNERODED TOPOGRAPHY
Subject to Revision According to
Studies Now in Progress
WISCONSIN
INDIANA
IOWA
JO DAVIESS
STEPHENSON
WINNEBAGO
BOONE
MC HENRY
LAKE
CARROLL
OGLE
DE KALB
KANE
DU PAGE
COOK
WHITESIDE
LEE
KENDALL
WILL
BUREAU
LA SALLE
GRUNDY
ROCK
MERCER
PUTNAM
STARK
MARSHALL
KANKAKEE
KNOX
WARREN
PEORIA
WOODFORD
LIVINGSTON
IROQUOIS
HANCOCK
MC DONOUGH
FULTON
TAZEWELL
FORD
MC LEAN
MASON
SCHUYLER
LOGAN
DEWITT
CHAMPAIGN
VERMILION
ADAMS
BROWN
MENARD
PIATT



LEGEND
1 ALLUVIAL DEPOSITS
2 MORE THAN 300 INCHES OF LOESS
3 150 TO 300 INCHES OF LOESS
4 100 TO 150 INCHES OF LOESS
5 75 TO 100 INCHES OF LOESS
6 50 TO 75 INCHES OF LOESS
7 25 TO 50 INCHES OF LOESS
8 LOESS NOT IDENTIFIABLE
WISCONSIN MORAINAL BORDER (Partly from Ill. Geol. Survey)
IOWAN TILL BORDER (After Kay)
Location of loess depth measurement
MISSOURI
KENTUCKY
GREENE
CALHOUN
JERSEY
MACOUPIN
MONTGOMERY
SHELBY
CUMBERLAND
CLARK
EFFINGHAM
FAYETTE
JASPER
CRAWFORD
BOND
MADISON
CLAY
RICHLAND
LAWRENCE
MARION
CLINTON
ST. CLAIR
WAYNE
WASHINGTON
JEFFERSON
EDWARDS
WABASH
MONROE
RANDOLPH
PERRY
HAMILTON
WHITE
FRANKLIN
SALINE
GALLATIN
JACKSON
WILLIAMSON
HARDIN
UNION
JOHNSON
POPE
ALEXANDER
PULASKI
MASSAC
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UNIVERSITY OF ILLINOIS AGRICULTURAL EXPERIMENT STATION
JANUARY, 1941

In every case the conformation of the deep loess deposits indicates that the prevailing winds at the time of loess deposition came from the northwest. Leighton[16*] reached a similar conclusion after study of the Iowan border loess.

The discontinuities in the loess depth lines at the Wisconsin morainal border and within the area covered by Wisconsin till indicate clearly that the loess deposition preceded the deposition of the till, and that it continued after the retreat of the early Wisconsin ice, as Leverett[20*] has pointed out.

VARIATIONS IN PROPERTIES OF PEORIAN LOESS

Particle Size

The variations in mechanical composition of the calcareous Peorian loess samples collected at varying distances from the river bluffs along Traverses 1 and 2 are given in Table 1. These data show that the coarser fractions decrease in quantity, the finer fractions increase in quantity, and the intermediate fractions first increase and then decrease with distance from the bluff. Within limits there is a linear relationship between particle size and the logarithm of the distance from the bluff. This relationship is shown in Fig. 4, where the percentages of 30-to-50 and 10-to-20 micron silt in the samples taken along Traverse 1 are plotted on semilog graph paper against distance from the bluff.

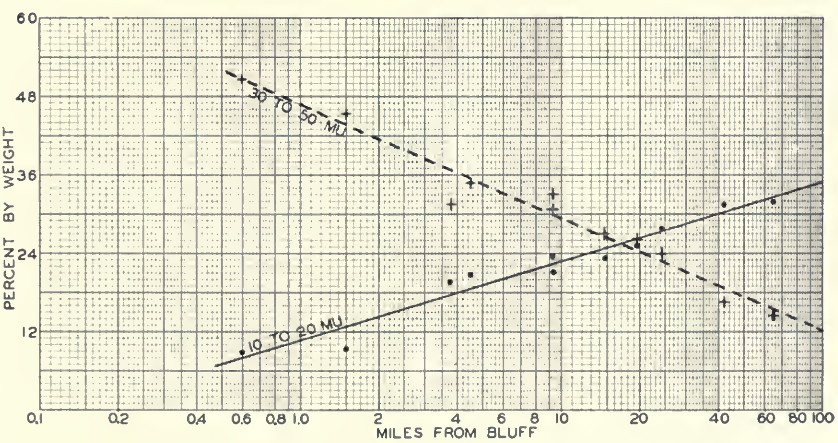

FIG. 4.—VARIATIONS IN PERCENTAGES OF 10-TO-20-MICRON SILT AND 30-TO-50-MICRON SILT IN CALCAREOUS PEORIAN LOESS WITH LOGARITHM OF DISTANCE FROM BLUFFS: TRAVERSE 1

TABLE 1.—VARIATIONS IN PARTICLE SIZE OF CALCAREOUS PEORIAN LOESS WITH DISTANCE FROM BLUFF: MENARD, SANGAMON, CHRISTIAN, SHELBY, ST. CLAIR COUNTIES

Traverse 1

Location	Sample No.	Distance from bluff	Mean size of silt and clay	Proportion of loess composed of— Sand	Silt and clay particles having diameters of— 50-30 μ	30-20 μ	20-10 μ	10-1 μ	<1 μ
Menard		*miles*	*microns*	*perct.*	*perct.*	*perct.*	*perct.*	*perct.*	*perct.*
T 19 N, R 7 W, Sec. 17, NW, NW	15125–27	.6	32.3	18.7	50.7	15.5	9.0	3.9	2.2
T 19 N, R 7 W, Sec. 17, SE, NW, SE	15524–28	1.5	30.6	21.5	45.3	14.1	9.4	6.3	3.4
T 19 N, R 7 W, Sec. 28, SE, NE, SE	15515–21	3.8	24.1	.8	31.7	32.9	19.9	6.8	7.5
T 19 N, R 7 W, Sec. 27, SE, SW	15128–31	4.5	24.4	2.7	34.9	24.6	20.8	10.9	6.1
T 18 N, R 6 W, Sec. 17, NW, SE, NW	15132–35	9.3	23.8	.7[a]	30.9	30.1	23.6	9.9	4.8
Across road from above	15509–14	9.3	23.7	1.4[a]	33.1	27.7	21.0	11.5	5.3
T 17 N, R 6 W, Sec. 2, SW, SW, SW	15722	14.7	22.2	1.0[a]	27.0	30.0	23.2	11.6	7.2
Sangamon									
T 17 N, R 5 W, Sec. 21, SW, SW	15136–41	19.6	21.5	.6[a]	26.1	27.2	25.2	13.7	7.2
T 16 N, R 5 W, Sec. 11, SE, SW	15530–36	24.2	20.5	1.0[a]	24.0	24.6	27.8	15.8	6.8
Christian									
T 14 N, R 3 W, Sec. 13, NE, NE, SE	15210–12	42	17.6	.9[a]	16.6	21.5	31.7	18.0	11.3
Shelby									
T 13 N, R 2 E, Sec. 26, NW, NW, NW	15724–27	65	16.4	1.7[a]	14.5	18.6	31.9	24.6	8.7

Traverse 2

Location	Sample No.	Distance from bluff	Mean size of silt and clay	Proportion of loess composed of— Sand	Silt and clay particles having diameters of— 50-30 μ	30-20 μ	20-5 μ	<5 μ
St. Clair		*miles*	*microns*	*perct.*	*perct.*	*perct.*	*perct.*	*perct.*
T 2 N, R 8 W, Sec. 7, SE, NE	15597–608	.1	28.0	1.6[b]	47.9	24.0	20.0	6.5
T 2 N, R 8 W, Sec. 4, SE, NE	15587–93	1.8	25.0	1.4[c]	28.6	25.0	25.0	10.0
T 2 N, R 8 W, Sec. 2, SW, NE, SW	15545–48	3.1	23.3	1.2[d]	33.3	24.5	28.5	12.5
T 2 N, R 7 W, Sec. 18, SW, NE	15611–15	5.3	23.0	1.0[d]	34.5	23.5	26.5	14.5
T 2 N, R 7 W, Sec. 17, NW, NE, NE	15550–52	6.5	21.7	.8[d]	28.2	25.5	31.5	14.0

[a]Lime and ferro-manganiferous concretions. [b]Mostly sand. [c]Partly sand. [d]Mostly lime and ferro-manganiferous concretions.

TABLE 2.—VARIATIONS IN PARTICLE SIZE OF SUBJACENT THIN HORIZONS OF CALCAREOUS PEORIAN LOESS: MENARD, SANGAMON, CHRISTIAN COUNTIES

Location	Thickness of loess	Sample No.	Depth to sample	Sand	Proportion of loess composed of— Silt and clay particles having diameters of— 50-40 μ	40-30 μ	30-20 μ	20-10 μ	10-1 μ	<1 μ
	inches		*inches*	*perct.*	*perct.*	*perct.*	*perct.*	*perct.*	*perct.*	*perct.*
Menard										
T 19 N, R 7 W, Sec. 17, NW, NW	(Not measured, about 40 feet)	15125	72–76	18.1	35.3	19.8	12.0	7.8	4.4	2.6
		15126	94–96	13.3	27.1	20.8	20.0	12.4	4.0	2.4
		15127	116–118	24.8	30.8	18.2	14.4	7.0	3.2	1.6
T 19 N, R 7 W, Sec. 27, SE, SW	246	15128	80–82	1.6	18.4	17.8	26.9	20.7	9.4	5.2
		15129	88–92	2.3	17.9	23.6	24.0	17.0	8.8	6.4
		15130	104–108	3.5	13.2	12.8	22.3	23.9	16.7	7.6
		15131	120–124	3.3	18.7	17.5	25.0	21.5	8.8	5.2
T 18 N, R 6 W, Sec. 17, NW, SE, NW	195	15132	112–115	.7[a]	13.4	16.7	28.2	26.6	10.4	4.0
		15133	122–124	.5[a]	9.7	19.7	34.5	23.4	8.6	3.6
		15134	141–143	.8[a]	13.1	19.3	28.0	23.1	9.8	5.9
		15135	154–156	.7[a]	14.0	17.8	29.7	21.4	10.9	5.5
Sangamon										
T 17 N, R 5 W, Sec. 21, SW, SW	125	15136	84–86	.6[a]	9.0	15.5	28.1	26.8	14.0	6.0
		15137	92–94	.7[a]	13.2	16.5	28.5	21.0	13.0	7.1
		15138	100–102	.7[a]	10.1	19.1	28.5	21.4	12.5	7.7
		15139	106–108	.6[a]	5.9	17.1	27.9	26.5	14.8	7.2
		15140	111–113	.5[a]	8.4	15.4	25.5	29.2	13.3	7.7
		15141	123–125	.6[a]	10.9	16.1	24.0	26.3	14.3	7.8
Christian										
T 14 N, R 3 W, Sec. 13, NE, NE, SE	88	15210	54–57	.5[a]	5.0	11.3	19.5	31.7	18.6	13.4
		15211	60–63	.7[a]	6.7	11.8	21.8	30.9	16.6	11.5
		15212	66–69	1.5[b]	4.7	10.3	23.1	32.7	18.7	9.0

[a]Ferro-manganiferous concretions. [b]Lime concretions.

Disregarding the sands, the arithmetic mean particle size of the silts and clays decreases with distance. Here again there is a linear relationship with the logarithm of the distance from the bluff, which is shown in Fig. 5. The relationship shown by Figs. 4 and 5 indicates that there are rapid changes in particle size close to the bluffs and only

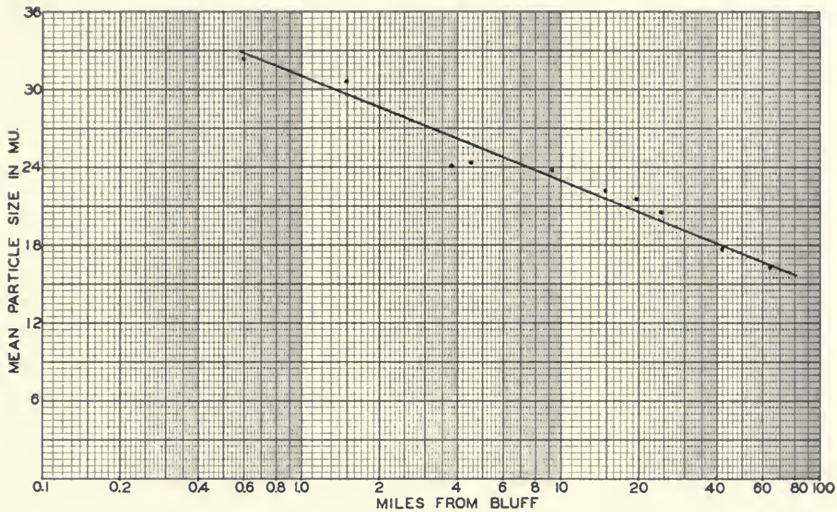

FIG. 5.—VARIATIONS IN MEAN PARTICLE SIZE OF CALCAREOUS PEORIAN LOESS WITH LOGARITHM OF DISTANCE FROM BLUFFS: TRAVERSE 1

small changes at a distance, and that particle size decreases by a constant number of units whenever the distance from the bluff is increased by a constant percentage of itself. This relation confirms Krumbein's prediction[15*] that changes in particle size with distance from the bluffs would be exponential.

To get some idea of the variability of the texture of the loess at any given spot, mechanical analyses were made of subjacent thin horizons taken from spots selected at random along Traverse 1. The results of these mechanical analyses are given in Table 2. The data indicate no apparent trend in size composition with depth in any profile; the variations are apparently random variations. The significance of these data are discussed on page 175.

Depth as Related to Distance From River Bluffs

The variations in the thickness of the loess blankets with distance from their source at the river bluffs, in a straight line along Traverse 1

TABLE 3.—CHANGE IN THICKNESS OF LOESS WITH DISTANCE FROM BLUFF: MENARD, SANGAMON, CHRISTIAN, SHELBY, EFFINGHAM, ST. CLAIR, CLINTON, JEFFERSON, AND CASS COUNTIES

Location	Distance from bluff	Thickness of loess— Total			
		Observed	Calculated[a]	Sangamon	Peorian
Traverse 1					
	miles	*inches*	*inches*	*inches*	*inches*
Menard					
T 19 N, R 7 W, Sec. 28, SE, NE	3.8	316	318	60	256
T 18 N, R 6 W, Sec. 17, NW, SE, NW	9.3	240	240	54	186
T 17 N, R 6 W, Sec. 2, SW, SW	14.7	220	201	55	165
Sangamon					
T 17 N, R 5 W, Sec. 21, SW, SW	19.6	165	176	40	125
T 16 N, R 5 W, Sec. 11, SE, SW	24.2	Part. eroded		38	Part. eroded
T 15 N, R 4 W, Sec. 16, NE, NW	32	137	133	34	103
T 14 N, R 3 W, Sec. 4, NW, NE	39	110	116	...	...
Christian					
T 14 N, R 3 W, Sec. 10, NW, NE	40	105	114	25	80
T 14 N, R 3 W, Sec. 11, NE, SE	41	110	112	15 +	95 −
T 14 N, R 3 W, Sec. 36, SW, SE	45	108	104	26	82
T 14 N, R 2 W, Sec. 31, NE, SE	45.5	(?)	...	(?)	78
T 13 N, R 2 W, Sec. 24, SW, SE	51	86	93	21	65
T 12 N, R 1 E, Sec. 34, SE, NE	65	72	72	...	...
T 11 N, R 1 E, Sec. 14, SW, SE	68	70	68	...	...
Shelby					
T 10 N, R 2 E, Sec. 16, NE, SE	75	58	59	...	...
T 9 N, R 3 E, Sec. 9, SW, NE	83	54	50	...	...
Effingham					
T 9 N, R 4 E, Sec. 30, NE, SW	87	45	46	...	...
T 7 N, R 5 E, Sec. 6, SE, SW	98	38	36	...	...
Traverse 2					
St. Clair					
T 2 N, R 8 W, Sec. 4, SE, NE	1.9	410	425[b]	150	260
T 2 N, R 8 W, Sec. 2, SW, NE	3.6	325	327[b]	127	198
T 2 N, R 8 W, Sec. 12, NE, NE	5.2	260	270[b]	124[d]	136[d]
T 2 N, R 7 W, Sec. 17, NW, NE	7.0	235	225[b]	90	145
T 2 N, R 7 W, Sec. 10, NW, NW	8.2	190	200[b]	65	125
T 2 N, R 6 W, Sec. 7, SE, SW	12.0	165	142[b]	...	...
T 2 N, R 6 W, Sec. 23, SE, SE	16.5	100	93[b]	...	...
Clinton					
T 2 N, R 5 W, Sec. 22, NW, NE	21	72	72[c]	...	...
T 2 N, R 5 W, Sec. 13, SE, SE	24	65	68[c]	...	...
T 2 N, R 3 W, Sec. 28, NW, SE	32	61	60[c]	...	...
T 1 N, R 1 W, Sec. 4, NE, SE	49	52	49[c]	...	...
T 2 N, R 1 W, Sec. 33, SE, SE	49	54	49[c]	...	...
Jefferson					
T 1 S, R 2 E, Sec. 10, NW, NE	61	41	43[c]	...	...
T 1 S, R 4 E, Sec. 6, NE, NE	70	36	40[c]	...	...
Cass county					
T 18 N, R 10 W, Sec. 16, NE, NE	.2	...	...	...	1100
T 18 N, R 10 W, Sec. 16, NE, SW	.5	...	...	...	815
T 18 N, R 9 W, Sec. 8, SE, NE	1.75	...	...	...	385
T 18 N, R 10 W, Sec. 23, NW, NE	2.0	...	...	...	320
T 18 N, R 10 W, Sec. 34, SE, NW	4.0	...	...	...	220
T 18 N, R 9 W, Sec. 34, NE, NW	5.5	...	...	...	210
T 17 N, R 9 W, Sec. 12, SE, NE	10.0	...	...	...	166

[a]Depths calculated from equation $Y = 434 - 200 \log X$. [b]Depths calculated from equation $Y = 523 - 352 \log X$. [c]Depths calculated from equation $Y = 153 - 62 \log X$. [d]Approximate thickness, boundary very indistinct.

thru Menard, Sangamon, Christian, Shelby, and Effingham counties, are shown in Table 3. It will be noted that when the total loess becomes thin, no separation is shown between the Peorian and Late Sangamon loess sheets. Measurements along this traverse were not made closer to the bluff than about four miles because of the absence of deep road cuts and the difficulty of making borings to a depth of more than about 20 feet with available instruments.

The changes in depth along Traverse 1 are shown graphically in Fig. 6. The equation for the curve fitted to the points in this graph is $Y = 434 - 200 \log X$, where Y equals the depth of the loess in inches and X equals the distance from the bluff in miles. This equation, together with the observed depths of loess, has been plotted in Fig. 7 on semilog graph paper for convenience in inspection. The loess depths calculated from this equation for the points where measurements were made will be found in Table 3.

The observations of loess depths along Traverse 2 thru St. Clair, Clinton, and Jefferson counties are also given in Table 3 and are shown graphically in Figs. 8 and 9. The equation for the curve fitted to these observations has the same form as the equation to Fig. 5, namely, $Y = a - b \log X$, but the constants in the equation seem to change at a distance of about 20 miles from the bluff. Between the limits of 2 and 20 miles the equation is $Y = 523 - 352 \log X$, while between 20 and 70 miles, the equation is $Y = 153 - 62 \log X$.

Since no change in the constants of the equation describing the thinning of the loess along Traverse 1 had been observed between 4 and 100 miles, an attempt was made to determine whether or not such a change occurred at some point less than four miles from the bluff. Accordingly a shift of about 12 miles to the west was made in the point of origin of this traverse to an area in Cass county where some deep cuts permitted the estimation of the loess depths close to the bluff. Owing to the great thickness of the loess, measurements of the thickness of the Late Sangamon loess were not always possible. The measurements of the Peorian loess thickness are recorded in Table 3. The two measurements closest to the bluff were estimated from the height of broad flat-topped divides above outcropping contacts between the Peorian and Late Sangamon loess sheets. The variations in the thickness of Peorian loess thru Cass, Menard, Sangamon and Christian counties are shown in Fig. 10. This figure shows that a change in the constants does occur in this area at a point about three miles from the bluff.

There is a very close resemblance between Figs. 8 and 9 and

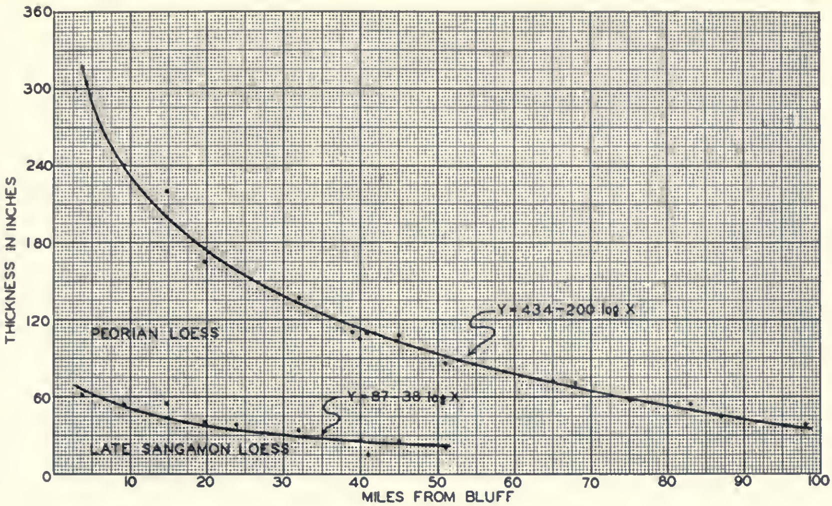

FIG. 6.—VARIATIONS IN THICKNESS OF PEORIAN AND LATE SANGAMON LOESS WITH DISTANCE FROM BLUFFS: TRAVERSE 1

Krumbein's graph[15*] of the loess depths along Mississippi river in Henderson county some 40 miles to the north of the point of origin of Traverse 1. All three graphs show an initial rapid but constant

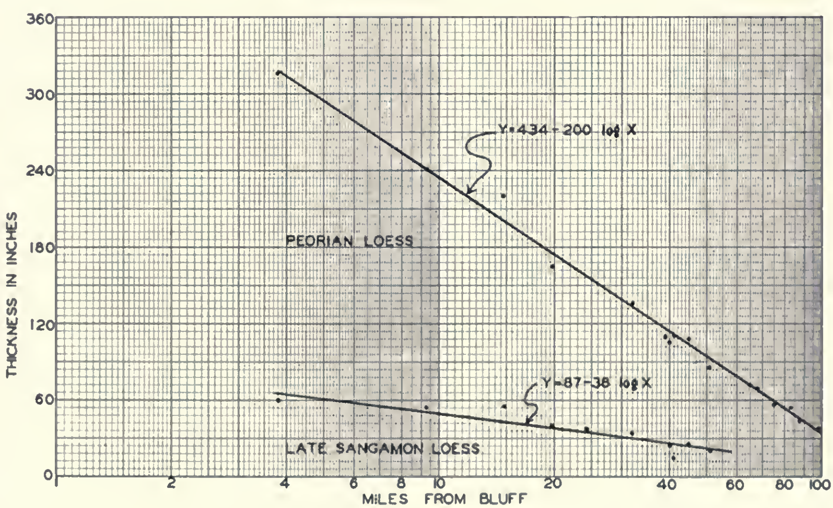

FIG. 7.—VARIATIONS IN THICKNESS OF PEORIAN AND LATE SANGAMON LOESS WITH LOGARITHM OF DISTANCE FROM BLUFFS: TRAVERSE 1

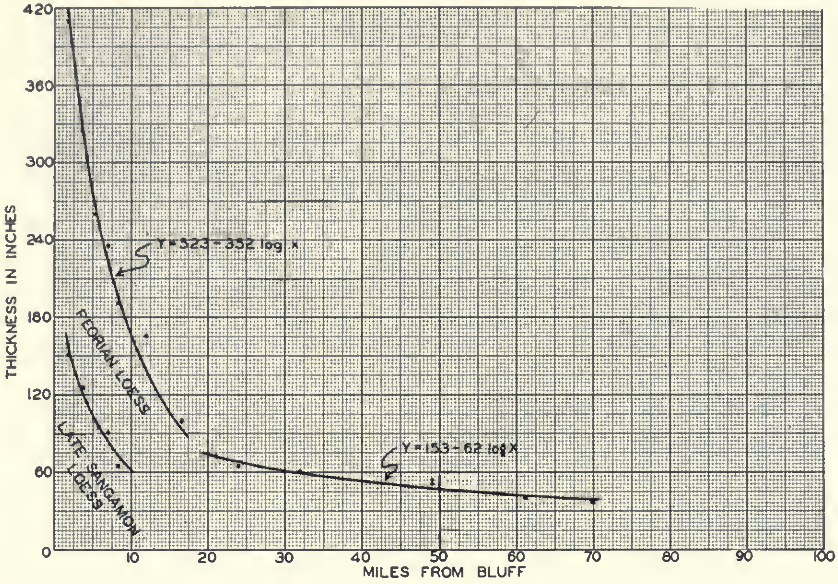

FIG. 8.—VARIATIONS IN THICKNESS OF PEORIAN AND LATE SANGAMON LOESS WITH DISTANCE FROM BLUFFS: TRAVERSE 2

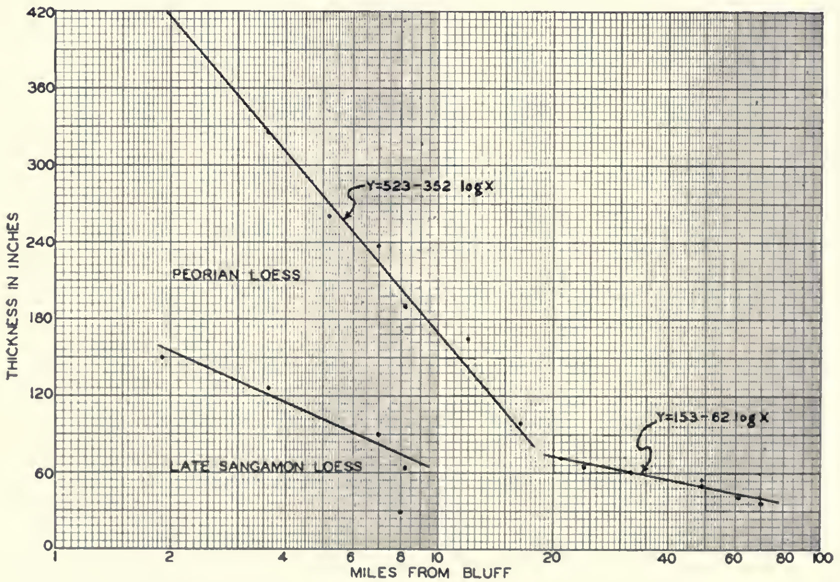

FIG. 9.—VARIATIONS IN THICKNESS OF PEORIAN AND LATE SANGAMON LOESS WITH LOGARITHM OF DISTANCE FROM BLUFFS: TRAVERSE 2

rate of change in the thinning of the loess, with a change at some point close to the bluffs. The equation which Krumbein used, however, put in log terms, becomes log $Y = a - bX$. This is in contrast to the equation $Y = a - b \log X$, developed in this study. Beyond distances of three or four miles from the bluff, either form of equation will fit

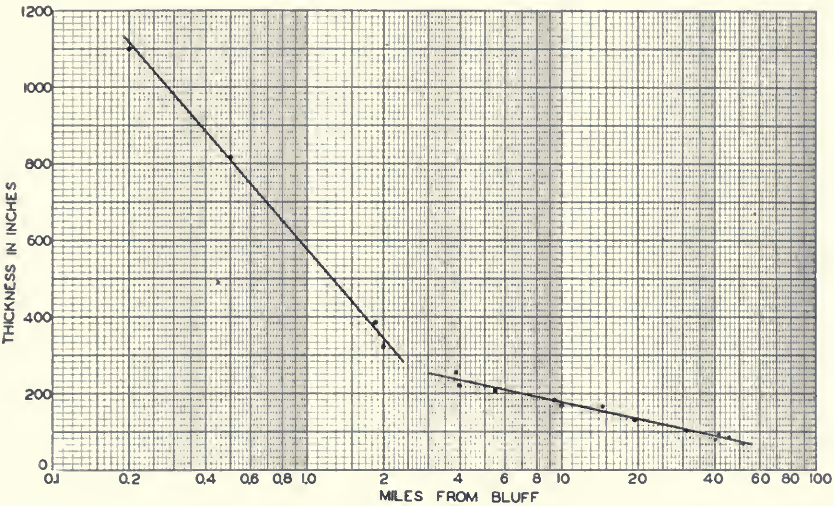

FIG. 10.—VARIATIONS IN THICKNESS OF PEORIAN LOESS WITH LOGARITHM OF DISTANCE FROM BLUFFS: TRAVERSE 1 AND CASS COUNTY

any of the three sets of data fairly well. Close to the bluff, however, the two equations are widely divergent. As stated earlier (*page 144*), Krumbein pointed out that his equation, if extrapolated to the bluff, would seriously underestimate the depth of the loess, but he explained that the greater thickness of the loess at the bluff might be due to the piling up of sand.

The equation $Y = a - b \log X$ would seem to be preferable to Krumbein's equation because of its better fit to the data at short distances from the bluffs. The form of equation used by Krumbein, if applied to the data from Traverse 2, would estimate the depth of loess at the bluff to be only about 450 inches. Extrapolation of the equation given in Fig. 9 for the loess thickness along Traverse 2 gives a loess depth of 875 inches at a distance of one-tenth mile from the bluff. The observed depth of the loess in an exposure at the bluff at Caseyville, near the point of origin of Traverse 2, is about 850 inches and the loess contains little or no sand. This observation was not included in

Table 3 because at the time it was made it was noted that there had been some opportunity for geologic erosion. Nevertheless there is close agreement with the extrapolation of the equation.

Krumbein,[15*] suggesting that the change in the constants of the equation for the loess thickness might have been produced thru particle-size differences, said, "It would seem that close to the source the loess settles out partly on the basis of relative grain size, but that beyond the point where significant size differences are present, the fine dust settles out more or less uniformly." The data on particle-size differences in the loess, presented in the accompanying tables and graphs, does not, however, support this suggestion. There is no indication in Figs. 4 and 5 that there is any point beyond which significant size differences will not be found. Nor can the greater thickness at the bluff be attributed to the piling up of sand, for there is little or no sand at the point of origin of Traverse 2 on the bluff.

A more logical explanation of the change in the constants of the equation expressing the thinning of the loess can be developed from the probability that the wind direction was not constant during the deposition of the loess. If the loess was deposited by winds of varying direction, the shape of the flood plains would bring about the observed phenomenon.[a] Study of the conformation of the bottomlands along Mississippi river near St. Clair county (Traverse 2) reveals that winds blowing from the northwest could deposit appreciable amounts of loess along Traverse 2 only to a distance of about 20 miles. The northwest winds reaching points along this traverse more than 20 miles from the bluffs would have had no chance to pick up appreciable quantities of loess. Winds blowing in a west-northwest direction would deposit loess along the entire length of the traverse. Winds from the southwest would deposit little loess at any point along Traverse 2. The loess thickness at points less than 20 miles from the bluff along this traverse would be the summation of the deposition by winds varying in direction from west to northwest, but at points beyond 20 miles the thickness would represent essentially the deposition by the west-northwest winds.

Study of the conformation of the bottomlands along Traverse 1 shows that the northwest winds and the west-northwest winds could have deposited loess along the entire length of the traverse but that winds from the southwest could have deposited appreciable amounts of loess only at points very close to the bluff.

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[a]The writer is indebted to E. J. Working, Department of Agricultural Economics, for the idea developed in this paragraph.

If the equation $Y = a - b \log X$ correctly describes the thinning of the loess, there is a finite distance beyond which the loess was not carried, and the slopes of the curves indicate that this distance was only a few hundred miles. For the fine silts to settle out within such a short distance it would be necessary to assume that the storms which deposited the loess either were of local character or that the dust was not carried high into the atmosphere.

In this connection it is interesting to note Thorp's[32*] description of the current deposition of loess in China. He says:

> "I have already pointed out in the discussion of loess of Northwest China that the mountain tops even there have received relatively little windblown dust. Most of it is deposited in the valleys and on hills, and when winds are whipping up great clouds of dust from the dry flood plains of North China the upper atmosphere is seldom very heavily charged with dust. Most of the dust moves fairly close to the surface of the land."

Thorp[33*] estimates that during the majority of the storms which he observed the dust was carried to heights of only a few hundred feet.

Depth as Influenced by Lodgment Factors

It should be pointed out in connection with the study of the loess thickness that the depth of loess at any given point is the resultant of two sets of forces—those of deposition and those of removal. Had the loess been deposited on a surface devoid of vegetation, it could subsequently have been picked up by the wind and redeposited at some other point. Hobbs[13*] has pointed out the influence of vegetation in the lodgment of the loess. In discussing the current deposition of loess in Greenland, he describes the collection of dust in the tundra and the tendency, in areas without vegetation, for the sediments to drift and to collect in the lee of objects which break the wind.

In Illinois in areas where one might reasonably assume the absence or scarcity of vegetation during the period of loess deposition, it is common to find relatively thin loess. Observations of the loess thickness in areas which were shallow lakes prior to artificial drainage frequently show the loess to be thinner than on the surrounding higher areas. Similarly, in the areas covered by the heavy-textured, slowly permeable Wisconsin till, the loess depth is often less than on the adjacent till having a texture more favorable to plant growth. It is believed that the thinner loess in these areas is due to the scarcity of vegetation to catch and hold the loess. The shallow lakes probably were covered by ice in the fall of the year, when loess deposition is thought to have been most rapid; and the loess deposited there could have been picked up by the winter winds and redeposited elsewhere.

Similarly the areas covered by heavy-textured till are thought to have been covered by vegetation more slowly than the areas of till having a favorable texture. The loess deposited on the heavy till would have been exposed to subsequent drifting and blowing by the winds.

Calcium Carbonate Equivalent

Measurements of the calcium carbonate equivalent of the Peorian loess show that in general in Illinois, as in Indiana, the carbonate content of the Peorian loess decreases as the loess becomes thinner.

Measurements of the carbonate contents of samples taken to represent the lower one-quarter of Peoria loess deposits of varying thick-

TABLE 4.—CALCIUM CARBONATE EQUIVALENT OF PEORIAN LOESS AS RELATED TO THICKNESS OF DEPOSIT

Location	Sample No.	Depth to sample	Thickness of loess	$CaCO_3$ equivalent: Observed	$CaCO_3$ equivalent: Calculated[a]
Illinois river loess: Cass, Menard, Sangamon counties					
		inches	*inches*	*perct.*	*perct.*
Cass					
T 18 N, R 10 W, Sec. 16, NE, SW	16045	500–550	815	39.2	37.6
T 18 N, R 9 W, Sec. 6, NE, SW	15737–46	450–600[b]	600	38.0	36.2
T 18 N, R 10 W, Sec. 23, NW, NE	15729–36	260–340[b]	340	33.8	32.1
Menard					
T 19 N, R 7 W, Sec. 28, SE, NE	15720	190–256[b]	256	28.1	29.0
Cass					
T 18 N, R 9 W, Sec. 24, NW, SE	16036	162–215[b]	222	23.0	27.1
T 18 N, R 10 W, Sec. 34, SE, NW	16039–40	155–215[b]	220	28.9	27.0
T 18 N, R 9 W, Sec. 34, NE, NW	16035	150–200[b]	210	25.8	26.2
Menard					
T 18 N, R 6 W, Sec. 17, NW, SE, NW	15133–35	120–160	195	23.4	25.1
T 18 N, R 6 W, Sec. 17, NW, SE, NW	15511–14	140–180[b]	186	21.1	24.3
T 17 N, R 6 W, Sec. 2, SW, SW, SW	15722	120–160[b]	165	18.6	22.0
Sangamon					
T 17 N, R 5 W, Sec. 30, NE, SE	16058	98–120	128	17.3	16.4
T 17 N, R 6 W, Sec. 28, SW, NE	16059	110–125	130	13.4	16.8
T 17 N, R 5 W, Sec. 21, SW, SW	15138–41	90–120[b]	125	20.1	15.8
T 16 N, R 5 W, Sec. 11, SE, SW	15530–35	90–120[b]	120	19.8	14.7
T 17 N, R 5 W, Sec. 36, NW, SW	16057	95–120	120	17.4	14.7
T 15 N, R 4 W, Sec. 16, NE, NW	15501–03	82–100	103	7.0	10.3
Mississippi river loess: St. Clair county					
		inches	*inches*	*perct.*	*perct.*[c]
T 2 N, R 8 W, Sec. 7, SE, NE	15597–608	570–720[d]	720	29.2	25.0
T 2 N, R 9 W, Sec. 24, SW, SE	16452	560–660	660	23.2	24.7
T 2 N, R 9 W, Sec. 25, NE, SE	16446	260–320[d]	340	17.7	20.7
T 2 N, R 8 W, Sec. 30, NW, SW	16447	240–290[d]	300	17.5	19.7
T 2 N, R 8 W, Sec. 30, SE, NW	16448	200–240[d]	250	18.4	17.9
T 2 N, R 8 W, Sec. 18, SE, SE	16453	180–215[d]	225	18.2	16.6
T 2 N, R 8 W, Sec. 4, SE, NE	15587–93	170–220[d]	225	16.8	16.6
T 1 N, R 9 W, Sec. 10, SE, NE	16449	164–204[d]	214	16.5	16.0
T 1 N, R 9 W, Sec. 1, SE, NE	16450	160–190[d]	200	13.5	15.1
T 1 N, R 8 W, Sec. 6, NE, SW	16451	160–190[d]	200	16.1	15.1
T 2 N, R 8 W, Sec. 2, Survey 583	15545–48	140–180[d]	198	15.2	15.0
T 2 N, R 7 W, Sec. 17, NW, NE	15550–52	125–145	145	10.0	9.9

[a]Calculated from equation: $Y = 41.6 - \frac{3200}{X}$ $S_{yx} = 2.8$. [b]Composite sample from lower one-fourth of Peorian loess. [c]Calculated from equation: $Y = 28.8 - \frac{2700}{X}$ $S_{yx} = 1.8$. [d]Composite sample from lower one-sixth of Peorian loess.

ness in the vicinities of Traverses 1 and 2 are given in Table 4. These samples were taken in Cass, Menard, and Sangamon counties close to Traverse 1 and in St. Clair county along Traverse 2.

Three hypotheses explaining such decreases, together with the study made to test them, are presented below:

(1) If the finer size groups of loess contained a lower percentage of carbonates than the coarse size groups, fractionation of the loess by the wind would produce a high carbonate loess at the bluffs and a lower carbonate loess at a distance.

To test this hypothesis, samples of deeply buried calcareous loess were taken from the lower quarter of the Peorian loess at varying

TABLE 5.—CALCIUM CARBONATE EQUIVALENT OF VARIOUS PARTICLE SIZE GROUPS OF PEORIAN LOESS

Size group	Samples 15737–46[a]	Sample 15720[a]	Samples 15530–36[a]
	perct.	*perct.*	*perct.*
Fine sand	8.2	([b])	([b])
Very fine sand	22.5	([b])	([b])
Silts			
50-40 microns	38.5	14.6	12.0[c]
40-30 microns	38.4	23.3	16.2
30-20 microns	36.3	36.0	23.5
20-10 microns	34.4	31.8	20.7
10- 5 microns	30.3	26.0	14.2
	miles	*miles*	*miles*
Distance from bluff	.1	3.8	24.2
	inches	*inches*	*inches*
Peorian loess depth	600+	256	123

[a]Fractionation by E. P. Whiteside. [b]Size not present in sample. [c]Approximate.

distances from the bluff along Traverse 1. These samples were fractionated into size groups, and the carbonate content of each size fraction was determined. The results are given in Table 5. These data reveal that the carbonate content in the samples taken at the bluff (Samples 15737-15746) decreases somewhat as the particle size decreases. However, the lowest carbonate content within the silt particles is 30 percent, whereas the carbonate content of many of the samples of loess taken along the same traverse is less than 20 percent (see Table 4). Unless the wind were able to fractionate the loess on some basis other than effective particle size,[a] it is difficult to see how a fractionation could produce a deposit with a carbonate content of less

[a]Effective particle size is determined by the rate of fall. If a given particle falls at the same rate as a sphere of given size, the effective size of the particle is considered to be the size of the sphere.

than 20 percent in one case while nearby it produced loess with no size fraction containing less than 30 percent carbonates. If fractionation were accomplished thru effective particle-size differences in the different minerals, particles of any given effective diameter should, at the time of their deposition, have had approximately the same carbonate content irrespective of the distance to which they had been blown.

Furthermore the comparison of given size fractions from the samples taken at varying distances from the bluff shows that the carbonate content of every size fraction decreases with distance from the bluff, the greatest decrease taking place in the coarsest size group. The data in Table 5, while inconsistent with the assumption that wind fractionation could have produced the observed decreases in carbonate content, are consistent with the assumption that the changes in carbonate content have been produced by a partial leaching.

If the differences in carbonate content had been brought about by a partial leaching, the most rapid apparent decrease in carbonates might easily occur in the largest size groups. The partial leaching of the loess would produce a relatively rapid change in the size of the carbonate particles compared with the other minerals present. Thus, in the loess, particles of calcite or dolomite which when deposited had effective diameters ranging between 40 and 50 microns would have smaller effective diameters after partial leaching. If such a loess were fractionated according to particle size before and after leaching, the coarsest size fraction would show a rapid loss of carbonates, partly owing to solution loss but primarily because the reduction in size of the carbonate particles would cause a portion of these particles to fall into one of the smaller size groups. The next smaller size group would likewise lose calcareous particles to still smaller size groups, but in compensation would be receiving calcareous particles from the larger size group. Thus the fact that the fractionation must be made on the basis of present particle size rather than original particle size could lead to an apparent rapid loss of carbonates in the largest size groups.

(2) Difficulties inherent in the method of sampling may have been responsible for an apparent rather than a real decrease in the carbonate content associated with differences in the thickness of the loess.

If it is assumed that downward percolating ground water moves several feet thru the calcareous loess before becoming saturated with the lime, then there should be present below the zone of complete leaching a zone in which the carbonate content increases with the depth below the leached zone. Under these conditions collection of samples from the lower quarter of the loess might result in apparent differences

in the carbonate content, for as the loess becomes thinner, samples must be taken closer and closer to the contact between calcareous and noncalcareous loess, until the zone of partially leached loess is included with the samples taken. The partially leached loess then would be sampled only where the loess is thin, not where the loess is thick.

To test this second hypothesis samples were taken at increasing depths, starting just below the leached loess, and the carbonate content was determined. The results are given in Table 6. As was pointed out earlier, if the ground water moves several feet thru a calcareous horizon before it becomes saturated with carbonates, the carbonate content of the loess should increase slowly thruout the distance required to saturate the ground water, and finally should reach a constant value.

The data in Table 6 show that the transition zone of partially leached material between the leached and unleached horizons, under the well-drained conditions from which these samples were taken, instead of being several feet thick, appears to be not more than an inch thick. Sample 15529, taken only an inch below the noncalcareous loess, has as high a content of carbonates as do any of the underlying horizons. Thruout each of the four sets of samples no evidence can be found that the first few inches of the calcareous loess contain any lower

TABLE 6.—CALCIUM CARBONATE EQUIVALENT OF SUBJACENT HORIZONS OF PEORIAN LOESS IMMEDIATELY BELOW NONCALCAREOUS LOESS: CASS, MENARD, AND SANGAMON COUNTIES

Location	Depth to carbonates	Sample No.	Depth to sample	$CaCO_3$ equivalent
	inches		*inches*	*perct.*
Cass				
T 18 N, R 10 W, Sec. 23, NW, NE	72	16029	80–105	27.3
		16030	105–130	29.9
		16031	130–155	26.2
		16032	155–180	25.4
		16033	180–205	27.4
		16034	205–230	27.6
Menard				
T 19 N, R 7 W, Sec. 27, SE, SW	66	16060	66–106	29.1
		16061	106–140	29.1
		16062	140–170	29.6
		16063	170–200	29.3
Sangamon				
T 17 N, R 5 W, Sec. 21, SW, SW	80	15136	84–86	19.6
		15137	92–94	21.3
		15138	100–102	19.0
		15139	106–108	19.8
		15140	111–113	20.6
		15141	123–125	21.2
T 16 N, R 5 W, Sec. 11, SE, SW	60	15529	61–62	23.6
		15530	66–68	23.2
		15531	70–72	23.7
		15532	74–76	22.9
		15533	80–82	18.1
		15534	84–86	18.0
		15535	88–90	17.1

percentage of carbonates than do the more deeply buried horizons. The data of Table 6 then would be consistent with the assumption that the carbonate contents of the samples collected have not been greatly modified by leaching since the close of the period of loess deposition.[a]

(3) A third possible cause of the differences in carbonate content between the thick and thin loess might have been a partial leaching of the loess during the period of loess deposition.

If the loess were deposited slowly under humid conditions, the probability of which the literature indicates, leaching during the period of deposition would have removed a measurable portion of the carbonates. If the ground waters became saturated with carbonates before penetrating any great distance into the loess, the total loss of carbonates by leaching would be the same at any distance from the bluffs under conditions of comparable drainage. If the total loss of carbonates were constant, the reduction in percentage of carbonates would be proportional to the reciprocal of the thickness of the deposits.

That the leaching took place during the period of loess deposition is the alternative possibility, however, if the changes in calcium carbonate equivalent between the thick and thin loess have been produced by leaching, as indicated by Table 5. It was pointed out that in such a case, the reduction in calcium carbonate equivalent should be inversely proportional to the thickness of the loess, and the determination of the constants of an equation of the type $Y = a - b\frac{1}{X}$ should permit the calculation of the changes in carbonate content. The equation expressing such a relation between the changes in calcium carbonate equivalent and the depth of loess, calculated from the data in Table 4 for Traverse 1, is $Y = 41.6 - \frac{3200}{X}$[b]. This equation and the observed carbonate contents are shown graphically in Fig. 11. Values for the various observed depths of loess were computed and are included in Table 4. The standard error of estimate, S_{yx}, is 2.8 percent, and there seems to be no evidence of any relationship other than linear between the calcium carbonate equivalent and the reciprocal of the loess depth.

The equation expressing the relationship between the $CaCO_3$ equivalent and the reciprocal of the loess depth, calculated from the data in Table 4 for Traverse 2, is $Y = 28.8 - \frac{2700}{X}$. This equation and

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[a]This observation will not necessarily apply to samples weathering under conditions of a high water table. [b]$Y = CaCO_3$ equivalent in percentage, $X =$ loess thickness in inches.

the observed carbonate contents are shown graphically in Fig. 11. Values for the various observed depths of loess were computed and are included in Table 4. The standard error of estimate, S_{yx}, is 1.8 percent. Again there seems to be no evidence of any relationship other than linear between the calcium carbonate equivalent and the reciprocal of the loess depth.

The constants in the equations $Y = 41.6 - \frac{3200}{X}$ and $Y = 28.8 - \frac{2700}{X}$ have a physical significance. The first constants, 41.6 and 28.8, represent the carbonate content of the loess at the time of deposition.

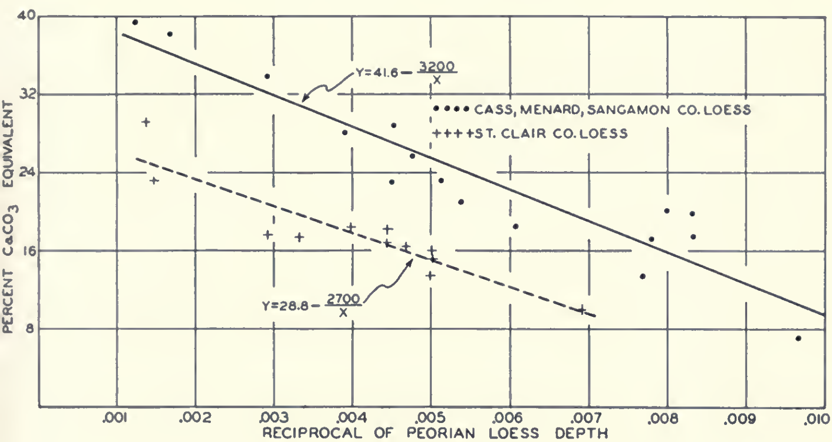


FIG. 11.—CaCo₃ EQUIVALENT OF PEORIAN LOESS AS RELATED TO RECIPROCAL OF LOESS DEPTH

Fig. 11 indicates that these values are probably significantly different. The second constants, 3200 and 2700, are measures of the loss of carbonates by leaching during the period of loess deposition. They indicate losses equivalent to layers of calcium carbonate loess particles 32 and 27 inches thick respectively. The difference between these values is not significant. The probable error of the constant 3200 is 280, while the probable error of the constant 2700 is 270. Sampling errors might easily be responsible for the difference in magnitude of the constants from the two equations, and statistically they must be considered to be approximately the same. The similarity in these constants strengthens the conclusion that the carbonate differences are due primarily to leaching during the period of deposition.

The measures of carbonate leaching during the period of loess

deposition can be compared with similar measures of the removal of carbonates subsequent to the period of loess deposition and will give an indication of the relative amounts of leaching during the two periods. The measure of the removal of carbonates by leaching subsequent to the period of loess deposition can be obtained by multiplying the depth of leaching of the loess-derived soil by the carbonate content of the underlying unleached loess. The carbonate loss will be underestimated by this method, for no allowance is made for the shrinkage of the soil due to the carbonate removal, but the comparative value of the measure is not affected by this error, for the same error exists in the measure of carbonate loss during the period of loess deposition.

Measurements of the loss of carbonates by leaching under a forest vegetation since the close of the period of loess deposition are given in Table 7. These measurements were made along Traverse 1 and show a loss equal to a layer of calcium carbonate particles 17.7 inches thick. A similar measure of the amount of leaching under a prairie vegetation, also given in Table 7, shows a loss equivalent to a layer of

TABLE 7.—REMOVAL OF CARBONATES BY LEACHING SINCE CLOSE OF LOESS DEPOSITION: CASS, MENARD, AND SANGAMON COUNTIES

Location	Sample No.	$CaCO_3$ equivalent	Depth of leaching	Carbonate loss
Under forest vegetation				
Cass		*perct.*	*inches*	*inches*
T 18 N, R 10 W, Sec. 23, NW, NE	16029	27.3	72	19.7
T 18 N, R 10 W, Sec. 34, SE, NW	16039	24.0	75	18.0
Sangamon				
T 17 N, R 5 W, Sec. 36, NW, SW	16057	17.4	90	15.7
T 17 N, R 5 W, Sec. 30, NE, SE	16058	17.3	93	16.1
T 17 N, R 5 W, Sec. 21, SW, SW	15138–41	20.1	92	18.6
T 17 N, R 6 W, Sec. 28, SW, NE	16059	13.4	104	13.9
Menard				
T 19 N, R 7 W, Sec. 27, SE, SW	16060	29.1	66	19.2
T 19 N, R 7 W, Sec. 27, NE, NE	16064	30.7	66	20.3
Mean				17.7 ± .5
Under grass vegetation				
Cass		*perct.*	*inches*	*inches*
T 17 N, R 11 W, Sec. 1, NW, NE	16047	23.7	47	11.2
T 17 N, R 11 W, Sec. 13, NE, SE	16048	25.2	46	11.6
T 17 N, R 11 W, Sec. 14, NW, SE	16049	27.1	44	12.0
T 17 N, R 11 W, Sec. 27, NW, SW	16050	29.4	45	13.2
T 17 N, R 11 W, Sec. 36, SE, NW	16051	24.1	43	10.4
T 17 N, R 10 W, Sec. 11, SE, SE	16052	31.0	34	10.5
T 17 N, R 10 W, Sec. 11, SE, SE	16053	31.6	44	13.9
T 17 N, R 9 W, Sec. 23, NW, SW	16054	22.8	50	11.4
T 17 N, R 8 W, Sec. 33, SE, NE	16055	26.0	42	10.9
T 17 N, R 8 W, Sec. 31, NE, NW	16056	26.4	48	12.6
Mean				11.8 ± .3

calcium carbonate particles 11.8 inches thick. Drainage conditions of all samples collected for study of the calcium carbonate equivalent were kept as nearly constant as possible, but a comparison of carbonate removal under forest vegetation and under grass vegetation shows that the natural vegetation had a significant effect on the amount of lime removed. A comparison, therefore, of the amounts of leaching during and subsequent to the period of deposition should be made if possible under similar vegetative covers. Since the evidence of the fossil life in the loess column indicates an arboreal vegetation near the bluffs (Baker[3*]) it seems best to compare the leaching loss during the period of loess deposition with the loss under a forest vegetation. Using the average of the two measurements of leaching loss during the period of loess deposition along Traverses 1 and 2, 32 and 27 inches respectively (*see page 169*), and the measure of leaching under a forest vegetation since the close of loess deposition, the following comparison is obtained:

Leaching loss since close of loess deposition...............	17.7 ± .5
Leaching loss during entire period of loess deposition.......	29.8 ± 3.0

Inasmuch as the samples for determining the leaching loss during the period of loess deposition were collected only from the lower one-fourth to one-sixth of the Peorian loess column, the data may not apply with equal validity to the upper three-fourths of the loess. The final conclusion must therefore be that the loss of carbonates since the close of loess deposition was approximately twice as great as the loss during the deposition of the first one-fourth of the Peorian loess.

The evidence that the loss of carbonates by leaching during the deposition of the first quarter of the Peorian loess was approximately half as great as the total loss subsequent to deposition is of interest as a measure of the time required to deposit the loess. The literature indicates relatively little difference in the climates of the two periods, and the rate of carbonate removal during the two periods should have been of the same order of magnitude. The relative loss of carbonates during the two periods would confirm Shimek's conclusion that deposition of the loess required considerable time.

The ratio of the measure of carbonate loss during the period of loess deposition to the measure of the carbonate loss subsequent to the period of loess deposition is 1.7. This is in close agreement with Antevs' estimates[2*] of the length of time since the Iowan and Mankato advances into Iowa. The ratio of the time between the Iowan and Mankato advances to the time since the Mankato advance is 1.8 according to Antevs' estimates.

PEDOLOGIC INTERPRETATION OF DATA

Character of Variations in Loess

It has been shown that the thickness of the loess and the size distribution of its particles tend to vary with the log of the distance from the source. If fractionation of the different minerals in the loess by the wind has been accomplished thru effective particle-size differences in the various minerals, it follows that mineralogic differences in the loess would also vary with the log of the distance from the source. Thus, if there were differences between the size distribution of the white micas and of the feldspars, the mineralogic composition of the loess might differ at varying distances from the bluffs. These differences, however, should be proportional to the log of the distance from the loess source. The differences in the first mile, between .1 and 1.0 mile from the bluff, should be at least equal to and might exceed the differences in the loess found between 10 and 100 miles from the bluff.

It has also been shown that the period of loess deposition was long. Along Illinois and Mississippi rivers, where the loess was most carefully studied, the period of loess deposition seems to have been longer and may have been almost twice as long as the period which has lapsed since the close of loess deposition. There should, then, be a significant difference in weathering between two soils developed from the same loess sheet if one of the soils is developed close to the bluff where the loess is thick and the other is developed where the loess is thin. The soil developed in very thick loess will have weathered from the loess laid down toward the close of the period of loess deposition and essentially will have been weathering only since loess deposition ceased. On the other hand, the solum of the soil developed in thin loess includes the first loess laid down as well as a very thin layer of loess laid down at the close of the period of deposition. In such case the soil has had an equal number of years to develop but has developed from material which had been greatly altered by weathering during the long period of loess deposition.

So great was this alteration that in large areas in southern Illinois weathering during the period of deposition probably removed all the free carbonates from the loess as rapidly as the loess was laid down. For example, the thickness of loess which, under well-drained conditions along Traverse 1, would have been leached of its free lime during the period of loess deposition can be estimated from the data in Table 4, giving the amount of carbonates removed by leaching during the period of loess deposition, and from the data in Table 7,

giving the relative losses under forest and grass vegetations since the close of loess deposition.

Under a forest vegetation along Traverse 1 in well-drained Peorian loess less than 80 inches thick, leaching should have removed the carbonates as rapidly as the loess was deposited. Similarly under a grass vegetation the well-drained Peorian loess that was less than 50 inches thick should have been noncalcareous at the close of the period of loess deposition. Greater depths of loess would have been subjected to lesser degrees of leaching. Along Traverse 2, under a forest vegetation, leaching should have removed the carbonates from the well-drained Peorian loess wherever it was less than 95 inches thick. Thus wide differences in the carbonate content of the loess would have been developed by the time loess deposition ceased. Concomitant changes of lesser magnitude in other minerals might reasonably be expected as a result of the weathering.

Loess Variations as Related to Grassland Catenas

The catenas which have developed under prairie vegetation have been located approximately along Traverse 1, and the variations in depth, particle size, $CaCO_3$ equivalent, and the effective age of the Peorian loess have been calculated. Table 8 shows the relation of the grassland catenas to these variations in the Peorian loess. It should be pointed out, however, that more field and laboratory work are needed before the boundaries, now tentatively established between the various catenas, can be considered to be final.

The thickness of the Peorian loess deposit in the region in which each catena is found was estimated from the data in Table 3, and the mean particle size of the loess was estimated from the relationship between particle size and distance from the bluff shown in Table 1. The

TABLE 8.—DERIVED DATA ON PARENT MATERIAL OF GRASSLAND CATENAS ALONG TRAVERSE 1

Catena	Distance from bluff	Depth of Peorian loess	Mean particle size	$CaCO_3$ equivalent at close of loess deposition[a]	Relative effective age of loess[b]
	miles	*inches*	*microns*	*perct.*	
Muscatine	3–45	>300–84	>28 –18.1	31–16	1.1–1.3
Ipava	45–55	84–65	18.1–17.1	16–7.4	1.3–1.45
Harrison	55–70	65–47	17.1–16.3	7.4–0	1.45–1.6
Cowden	70–90	47–30	16.3–15.7	0	1.6–1.9
Cisne	>90	<30	<15.7	0	1.9+

[a]$CaCO_3$ equivalent of well-drained loess deposited under grass vegetation. [b]Relative age of upper 30 inches of Peorian loess. Base period: 1 = time which has lapsed since close of loess deposition.

$CaCO_3$ equivalent of the loess at the close of the period of loess deposition was estimated from the relationship between depth of loess and carbonate content (Table 4) and adjusted for a grass vegetation by the ratio of carbonate removal under timber to that under grass vegetation (Table 7).

The relative effective ages have been estimated from the carbonate losses during and subsequent to the period of loess deposition.[a] If the assumption is made that the loss of free carbonates is a fairly sensitive measure of the degree of base removal to which the soil has been subjected, then the leaching losses are measures of the degree of weathering, or the relative ages of the parent materials.

An example of this estimation follows:

Loss of carbonates since close of loess deposition, 17.7 = 1 time unit
Loss of carbonates during loess deposition, 29.8 = 1.7 time units

Average age of upper 30 inches of 300-inch loess deposit	*Time unit*
Time since close of loess deposition	1.0
Plus ½ of time required to deposit the upper one-tenth of the loess, $\frac{1.7}{10} \times \frac{1}{2}$	.1
Total	1.1

Average age of 30-inch loess deposit	*Time unit*
Time since close of loess deposition	1.0
Plus ½ of time required to deposit the loess, 1.7 × ½	.85
Total	1.85

If there have been one or more periods of aridity subsequent to the retreat of the Wisconsin ice, as Sears[26*] and others have suggested, leaching losses would not be valid measures of the time interval. They would, however, be valid measures of the exposure to podsolic weathering during the humid periods, and it is this exposure which is meant by the term "effective age."

The validity of the estimate of effective age rests on the assumption that the rate of deposition of the first quarter of the Peorian loess was essentially the same as that of the other three quarters. It was pointed out (*on page 171*) that the measure of leaching during the period of loess deposition is based on samples representing only the lower one-fourth of the Peorian loess.

The rate of deposition might have been affected by three variables: first, the texture of the alluvial deposits, whether sandy, silty, or heavy; second, the width of the flood plain; third, the velocity of the wind. Variations in the texture of the alluvial deposits cannot at present be

[a]The use of the terms "time units" and "relative effective ages" should not be interpreted to mean years alone. Rather, it should be interpreted as the length of exposure to effective podsolic weathering.

evaluated, but some judgment can be formed of probable variations in the width of the flood plains. The field evidence indicates that the existing drainages along Illinois river were well established before the loess was deposited, for well-developed soils are found buried under the loess in the Illinoian till sloping down into the present valleys. While it might seem that the width of the flood plains should have increased somewhat as the streams carried away the melting waters of the Wisconsin ice, it must be remembered that the Illinois river valley was aggrading during this period, and bank cutting must have been at a minimum. Great changes in width of valley would therefore not be expected to have taken place during loess deposition.

The third process by which the rate of deposition might have been affected, as mentioned above, is thru an increase or decrease in wind velocities, for the carrying power of the wind varies with the sixth power of the velocity (see Udden[35*]). Changes in velocity, if continued over a long period, would produce changes in the texture of the loess, and the data in Table 2 reveal no trend toward a coarser or finer texture in the samples collected from subjacent horizons.

There would seem then to be little reason to suspect any marked change in the rate of deposition of the first quarter of the Peorian loess and the later portions.

A check on the reliability of the estimates of the relative lengths of the two time intervals can be secured from Antevs' estimates of the absolute length of the melting period of the Wisconsin ice. As was mentioned earlier (*page 143*), Antevs estimated that the interval between the Iowan and the Mankato advances was approximately 45,000 years and that the Mankato ice retreated from Iowa about 25,000 years ago. When it is considered that a portion of the Peorian loess antedates the Shelbyville moraine, and that the loess overlies portions of the Shelbyville, Bloomington, and Marsailles moraines without weathered contacts, it will be realized that the period of loess deposition in Illinois must have continued thru two of the four stages of the Wisconsin glaciation: namely, the Iowan and the Tazewell, as defined by Leighton.[18*] The loess deposition may have continued thru the Cary and Mankato stages, but the deposits of these ages are so distant from the loess sources that identification of the loess is difficult. However, Mississippi river must have carried the melting waters from these stages. In general, then, it may be said that while no claim can be made to a high degree of accuracy in estimating the age of the loess, the values in Table 8 should give the relative order of magnitude of the differences in age of the upper 30 inches of loess in thin and thick deposits along Traverse 1.

Relative Influence of Variables on Soil Character

Whenever a dependent variable changes with a number of closely related variables, it is of course difficult if not impossible to determine which of the independent variables have affected the dependent variable. In this study the dependent variable, soil character, is correlated with differences in (1) distance from the source of loess, (2) thickness of the loess, (3) the texture of the loess, (4) the lime content, and (5) the age of the loess in which the solum has developed.

The relative importance of each of these variables in determining soil character may be expected to vary in different sections of the country. A few conclusions, however, can be drawn from Table 8 about those soils along Traverse 1 developed under grass vegetation.

Distance from loess source. The geographic position of each catena might produce an effect on soil character if climatic variations were associated with the different geographic positions. In Illinois, however, the climate, rainfall, and temperature vary from north to south, whereas the soil character varies from east to west. The geographic position of the soils, therefore, should not have affected the soil character.

Loess depth. The loess depth might have an effect on the direction or rate of soil development, other factors being constant, if the underlying material were close enough to the surface to make its influence felt. Bray[6*] has suggested that the slowly permeable Illinoian till soil which underlies the thin loess has influenced the drainage conditions under which the soils developed and has thereby had an influence on the relative rate of development.

Differences in the drainage of the soils developed in thick and thin loess respectively do not readily account for the differences in base saturation and horizon development between the soils of the two areas (*page 147*). Soils developed in the thin loess show a low base saturation and a high degree of clay eluviation whether the topography be depressional or rolling, or whether drainage be very poor or moderately good. On the other hand, the soils developed in the thick loess show a high degree of base saturation and relatively little evidence of clay movement from the A into the B horizons under conditions of either good or poor drainage. If the drainage were the controlling factor, the poorly drained soils should closely resemble each other, irrespective of the depth of the loess in which the soils have developed, for an impervious substratum will check underdrainage in depressional areas or broad flats whether the tight layer be 3 feet or 6 feet below the surface. Furthermore, impeded underdrainage would retard rather

than accelerate the leaching of bases, for it will reduce the volume of water passing thru the soil.

There are other ways, however, in which underlying material can influence soil development. The substratum, when not too deeply buried, might affect the rate of weathering of the surface material if bases were moved upward by plant feeding or if there were mixing of the underlying and surface materials by animals. Field observations indicate great differences between the soils in regions of thick and thin Peorian loess in both the number and species of earthworms present. Earthworms are most abundant in the soils developed in the thicker loess, but no quantitative estimates have been made of the amount of mixing which has taken place.

The return of bases to the surface thru feeding by plants may also have been a factor in producing soil differences. Where the loess is thick, the solum is underlain by slightly weathered or calcareous loess. Where the loess is thin, the solum is underlain by weathered materials—the Late Sangamon loess and the Illinoian till. The presence of an abundant supply of bases in the substratum in regions of thick loess and the absence of this supply in regions of thin loess might result in differences in the vigor of the native grasses, the rate of leaching of the loess, and the rate of horizon development.

Particle size. The data in Table 8 make it seem improbable that the profile differences along Traverse 1 can be due to a fractionation of the loess by the wind. As was pointed out on page 172, fractionation by the wind could have taken place if differences in particle size existed among the various minerals. However, the greater part of the change in mean particle size takes place within the range of distance from the loess source covered by the Muscatine catena; there is much more range within that catena than in the combined Ipava, Herrick, Cowden, and Cisne catenas. Thus it will be seen that along Traverse 1 wide changes in the size of the loess particles are not associated with significant visible differences in soil characteristics, and that the wide differences in profile characteristics are found in soils developed from loess of nearly uniform texture. It should be pointed out, however, that in Menard county Prairie soils found within a mile of the loess source seem to belong to a different catena. Differences in particle size might be responsible for the presence of this additional catena, but further study is needed before conclusions can be drawn.

There is further possibility that mineralogic differences in the surface portion of the loess may not be related to particle-size differences. If the mineralogic composition of the Peorian loess varied widely from

the Iowan to the Mankato stages, significant differences might exist in the upper two or three feet of the loess deposit at different distances from the source. Close to the source the upper 3 feet might all be of Mankato age, while 75 miles away the upper 3 feet might include the entire Peorian loess sheet. Mineralogic studies are needed to determine whether differences exist between early and late Peorian deposits.

Calcium carbonate equivalent. Lime has long been considered as an agent which retards the rate of soil development. The fact that the lime content of the loess decreases with distance from the source at the bluffs might be used as an explanation of the differences in soil character. The data in Table 8 indicate that the well-drained members of Cisne and Cowden catenas have developed from loess which, by the close of the period of loess deposition, had been leached of its free lime, while the soils found at decreasing distances from the loess source have developed from a parent material of increasing carbonate content.

It is difficult, however, to attribute much of the difference in soil character to the differences in the lime content of the loess. Along Traverse 1 the carbonate content of the well-drained loess from which members of the Muscatine catena developed ranges from 16 to 31 percent (Table 8). If the carbonate content of the loess were the controlling factor, members of the Muscatine catena should not be formed in low-carbonate loess from other sources. The loess along the upper Mississippi Valley is relatively low in carbonates, samples from Henderson and Warren counties ranging from 12 to 20 percent $CaCO_3$ equivalent, and yet the Muscatine catena is dominant in prairie areas in these counties. If the carbonate content were the controlling factor, the Ipava catena should be present in these areas.

Another reason why the profile differences should not be attributed to differences in the carbonate content of the parent loess is that the differences in carbonate content of the loess have arisen, not from wind fractionation, but from differences in the degree of leaching during the period of loess deposition. The unweathered loess deposited at varying distances from the source along Traverse 1 must have had a nearly uniform carbonate content; and even if the soil differences were due directly to the lime differences, the ultimate cause of both the lime and the soil differences would be the variations in the effective age of the loess.

Age. It has been shown in Table 8 that differences in soil character are associated with differences in the effective age, or the relative exposure to weathering, of the soil's parent material, the Peorian loess.

It will be helpful to consider briefly the character of the changes which would be expected to take place with increasing age in the Prairie soils. For this purpose it is necessary to assume that the removal of weathered materials thru geologic erosion is going on at a slower rate than decomposition and weathering of primary minerals.

Gieseking[12*] has shown that under Illinois' climatic conditions, weathering under a prairie vegetation is podsolic in character, for the iron and aluminum are removed from the A horizon and accumulate in the B horizon, while silicon, being relatively less subject to translocation, tends to accumulate in the A horizon. The ratio of iron and aluminum to silicon should therefore decrease in the A horizon with age and should increase in the B horizon.

Under the influence of downward-moving ground waters, the bases are progressively leached from the solum, and the ratio of bases to silicon should also decrease with age.

Marbut[21*] recognized these trends when he pointed out that a grass vegetation is unable to prevent the loss of bases by leaching, and stated that the saturation with bases should decrease and acidity increase with the age of the Prairie soil. Marbut also stated that with progressive leaching, the supply of organic matter in the Prairie soils should decrease and the degree of eluviation and illuviation should increase.

If one examines the character of the profile differences exhibited among the soils found at various points along Traverse 1, where the parent material has been shown to be similar in character but of different effective age, he finds precisely the differences which have been outlined above.

Bray has pointed out, for a series of soils sampled along Traverse 1, that, among other things, wide differences exist in the degree of eluviation, the saturation with bases, and the content of organic carbon. From Bray's unpublished data, the molecular ratios of the sesqui-oxids to silica, and of calcium, magnesium, and potassium to silica have been calculated in this report for the A horizons of the soils sampled along Traverse 1. These values are given in Table 9. It will be observed that the molecular ratios of the bases, and of the sesqui-oxids to silica show progressive decreases between the samples subjected to increasing exposure to weathering.

Gieseking[12*] has shown the same decrease in the ratio of aluminum, or iron to silica in a series of samples collected from other sections of the state, and has shown an increase in the aluminum silicon ratio in the B horizons.

It may be argued that all of the soils chosen for study have de-

TABLE 9.—MOLECULAR RATIOS OF BASES AND SESQUI-OXIDS TO SiO_2 FOR CALCAREOUS LOESS AND A HORIZONS OF GRASSLAND CATENAS ALONG TRAVERSE 1

Horizon	Sample No.	$\frac{K, Ca, Mg}{SiO_2}$	$\frac{R_2O_3}{SiO_2}$
Calcareous loess (corrected for carbonates)	14061-62	.051	.098
A—Muscatine catena	14052	.045	.086
A—Harrison catena	14065	.032	.073
A—Cowden catena	14075	.029	.072
A—Cisne catena	14083	.023	.068

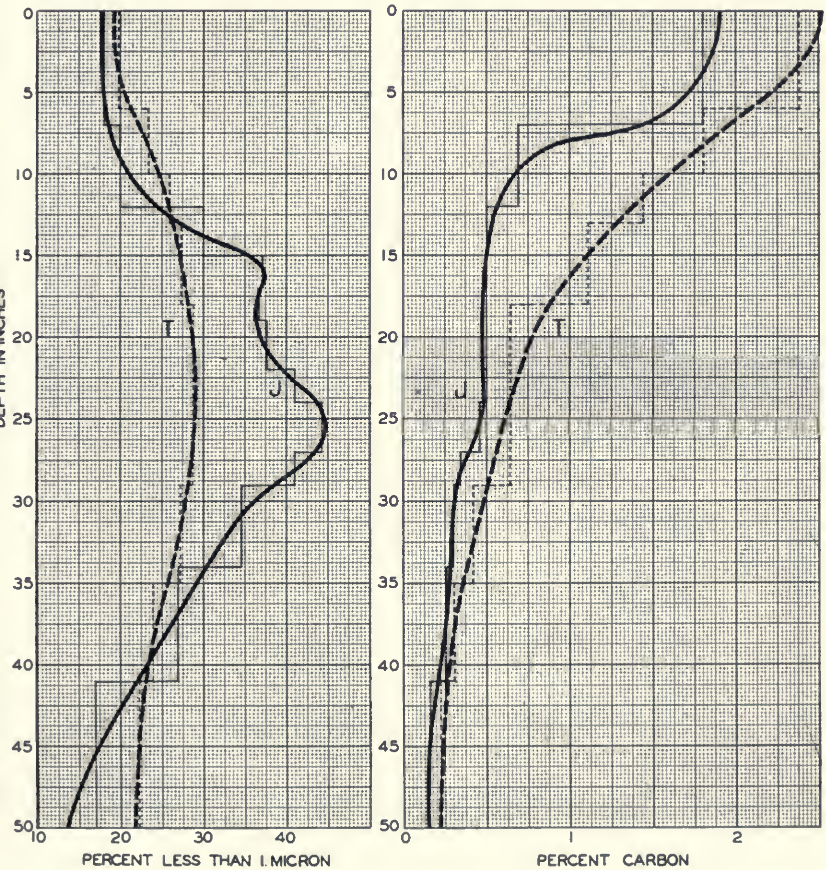
veloped under conditions of moderately poor drainage, and hence do not represent the "normal" weathering processes, which by definition are confined to the gently undulating upland with good drainage.

As mentioned earlier (*page 145*), Norton[22*] pointed out that the differences in profile characteristics just described are not confined to the poorly drained soils, but he published no data on the better drained soils. To illustrate the character of the profile differences between the soils developed on "normal" slopes, graphs are presented (Figs. 12 to 15) showing the distribution of colloidal material less than 1 micron in effective diameter, the organic carbon, the base exchange capacity, and the saturation with bases of representative profiles of Tama silt loam and Jasper silt loam.

Jasper silt loam is the best drained member of the Cisne catena. It has developed under a grass vegetation from thin loess on rolling slopes, with gradients ranging between 3½ and about 6 percent. Tama silt loam is a Prairie soil, developed from thick loess on slopes comparable to those of the Jasper. It will be observed that the Jasper bears the same relationship to Tama that Cisne bears to Muscatine (Fig. 1); Cisne and Muscatine are less well-drained types. The Jasper profile shows greater eluviation and illuviation, has less organic carbon, and is less highly saturated than is the Tama. The Jasper, even tho occurring on rolling slopes, is approaching the condition of a Planosol. Normal, or geologic, erosion has been slight on the Jasper profile, the total loess thickness being approximately the same in this profile as it is on the adjacent flats, where there has been no opportunity for erosion. The differences between the better-drained profiles are those which would be expected if the profiles were of different age. Table 8 shows that the soils have been exposed to different amounts of weathering.

It may be concluded, therefore, that the soils with good surface drainage differ in the same respects as do the poorly drained soils provided geologic erosion has been slow. It must also be concluded

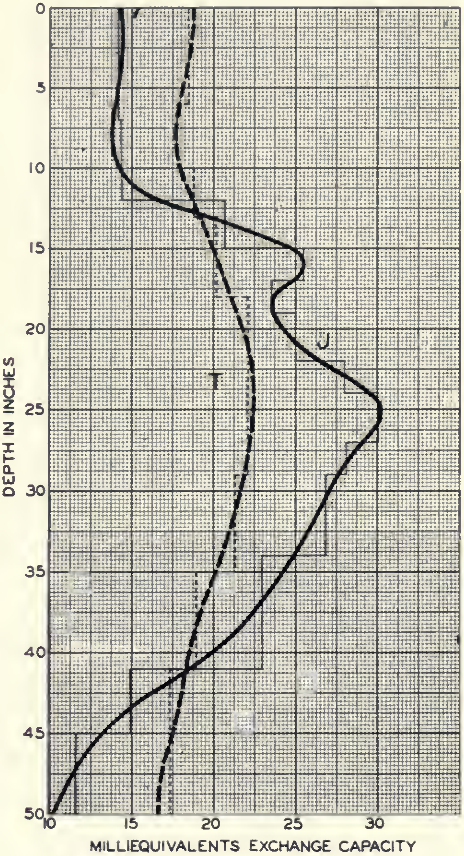
that the differences between the soils along Traverse 1 are those that would be expected to result from differences in age. This being the case, it seems logical to conclude that the Prairie soils, in the absence of geologic or normal erosion, are not in equilibrium with their environment, and that, given the proper content of primary minerals, many of them under their native environment would in time have become Planosols. The Prairie soils then would represent a special case in which the action of the native vegetation retarded and modified slightly the weathering of geologically very young parent materials.

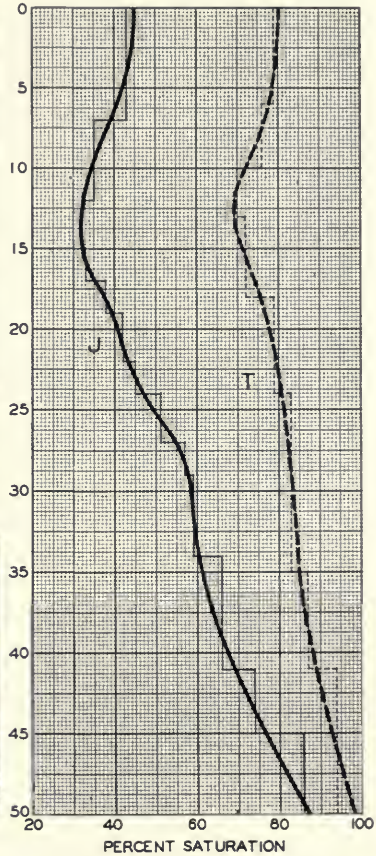


(T = Tama silt loam, J = Jasper silt loam)

FIG. 12.—DISTRIBUTION OF COLLOIDS (LESS THAN 1 MICRON) IN TAMA AND JASPER SILT LOAMS

FIG. 13.—DISTRIBUTION OF CARBON IN TAMA AND JASPER SILT LOAMS





(T = Tama silt loam, J = Jasper silt loam)

FIG. 14.—BASE-EXCHANGE CAPACITY OF TAMA AND JASPER SILT LOAM PROFILES

FIG. 15.—PERCENT SATURATION OF BASE-EXCHANGE COMPLEX OF TAMA AND JASPER SILT LOAM PROFILES

SUMMARY AND CONCLUSIONS

This bulletin is a progress report on a study of the loess in Illinois as a parent material from which soils have been formed. Primary attention has been given to the distribution of the loess deposits and to the relation between the character of these deposits and the distance from their source.

The conclusions reached may be summarized as follows:

1. Differences in the texture of the loess bear, within limits, a linear relation to the logarithm of the distance from the river bluffs.

2. The rate of the thinning of the loess with the distance from its source is a linear function of the logarithm of the distance.

3. The carbonate content of the loess decreases as the loess becomes thinner. The relation between the carbonate content and the loess thickness is expressed by the equation $Y = a - \frac{b}{X}$, when Y equals the percent of carbonates, X equals the thickness of the loess, a equals the carbonate content of the loess at the time of deposition, and b equals the loss of carbonates by leaching during the period of deposition.

4. The carbonate loss due to leaching during the deposition of the first quarter of the Peorian loess was approximately half as great as the leaching loss in the entire period subsequent to the loess deposition, showing there was a very slow deposition of the loess.

5. The differences in the profiles of the grassland soils found in loess deposits of varying thicknesses are attributed (1) to the differences in the age of that portion of the loess in which the solum is developed, and (2) to a possible influence of the substratum either thru direct mixing with the loess by animals or thru the return of bases or other nutrient elements to the surface by the grasses.

6. Many of the Prairie soils are not in equilibrium with their environment; the direction of their development is toward the condition of the Planosols.

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